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Knowledge Networks For Future Force Training: Illustration Of Searching, Retrieval, And Communication Concepts

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14. ABSTRACT *(Maximum 200 words)*:

U.S. Army units are transforming to become a lighter, more mobile Future Force that can operate within joint and coalition environments. To enable Future Force units to achieve successful deployment, the Army is developing knowledge networks to provide access to a wide range of information across military operations. To use the vast amount of available information effectively, knowledge networks must include procedures that organize information, identify the most relevant information to meet a user request, authenticate retrieved information, and allow the user to add new information to the network. This project develops and demonstrates a prototype knowledge network that illustrates methods to retrieve information needed to facilitate mission accomplishment, and to share this information among Soldiers and units.

This research began with an information engineering activity that analyzed the functions and tasks of Future Force units to identify information requirements. The effort proceeded to develop a prototype knowledge network incorporating relevant existing technologies, including (a) Web crawlers, (b) searching and indexing, (c) rich site summary news feeds, (d) Web logs, (e) user profiling, and (f) personal messaging. The prototype was demonstrated to four Army officers and enlisted personnel, whose impressions provided feedback used to revise the prototype and to make recommendations for future system enhancements.

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FOREWORD

The U.S. Army has initiated transformation to a Future Force designed to be responsive, deployable, agile, versatile, lethal, survivable, and sustainable to meet the full spectrum of future missions. Ready access to repositories of information will be critical to the success of the Future Force. Knowledge networks will be needed to support such access, providing reach capabilities for entering knowledge into repositories as well as extracting it from them. For many years the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been involved in the identification of knowledge requirements and development of methods for satisfying them, particularly in the arena of training. Further identification and development needs to be accomplished for the Future Force environment.

This report provides an overview of knowledge network capabilities needed by the Future Force and of an initial prototype network developed to provide such capabilities, with a focus on training support. It also provides the results of initial review and refinement of the prototype network, along with identification of further research and development needed. The work supporting this report was performed as part of Work Package 212, "Unit Training Technologies for Future Forces." The relevant requirements document is a Memorandum for Record between the Deputy Director, Unit of Action Maneuver Battle Laboratory (UAMBL), U.S. Army Armor Center and Fort Knox and the Chief, ARI Armored Forces Research Unit at Fort Knox, entitled "Research and Development Related to Training Methods for Objective Force Units of Action Equipped with Future Combat Systems," dated 10 September 2002.

The results of this effort were demonstrated and briefed to representatives of the UAMBL on 28 and 29 May 2003; the project team refined the prototype based on feedback received during those sessions. The analysis completed and prototype developed should be highly useful to personnel in the UAMBL, the U.S. Army Training and Doctrine Command, and other agencies responsible for development and implementation of knowledge networks for the Future Force over the next several years.

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KNOWLEDGE NETWORKS FOR FUTURE FORCE TRAINING: ILLUSTRATION OF SEARCHING, RETRIEVAL, AND COMMUNICATION CONCEPTS

EXECUTIVE SUMMARY

Research Requirement:

The U.S. Army is changing the structure and organization of units to produce a lighter, more mobile Future Force that can operate within joint and coalition environments. The primary Future Force tactical element will be the Unit of Action (UA), roughly equivalent to a brigade of today. One key to the success of the Future Force is the ability of units and their commanders to have accurate and timely knowledge about the mission, terrain, status of friendly and enemy combatants, cultural characteristics, weather, and other situational information. Other information will be required to provide training and performance support to Future Force units. Much of this information will be available in digital format from any of a variety of private and military databases, file servers, and other electronically linked sites.

To meet information needs for UA operations and training, the Army is developing knowledge networks (KNs) that will provide access to information from a wide range of sources to support the full spectrum of military operations. The KNs will incorporate various technologies to disseminate relevant information to meet the needs of Soldiers and their units. These include databases managed by Army organizations, links to relevant information sources, advanced search tools, innovative displays, and information-sharing capabilities. In addition, the KNs are planned to include procedures that allow the Soldier to add new relevant information and lessons learned to appropriate information repositories.

The research described in this report seeks to evaluate the potential of current and emerging technologies for information storage, distribution, and retrieval to support Soldiers in the Future Force who must meet specific information requirements (IRs) or who must communicate to others the information obtained. The overall goal of the effort was to develop a prototype system that illustrates how these technologies could be used to support the information sharing process.

Procedure:

This research began with an information engineering activity that analyzed the functions and tasks of Future Force units to identify IR. In order to provide a reasonable demonstration, the analysis focused on two functional areas—Civil Military Operations (CMO) and Intelligence. The result of the information engineering activity was a scenario that would stimulate the requirement for information from a variety of sources. We then developed a prototype knowledge network that incorporated several existing and emerging technologies related to information search, retrieval, and dissemination in a web portal design. Methods employed in the prototype included: (a) Web crawlers, (b) several methods for information searching and indexing, (c) rich site summary news feeds, (d) Web logs, (e) user profiling, and (f) personal

messaging. The information incorporated in the prototype knowledge network combined existing information from military and civilian sources with notional information designed to represent the future situation and units incorporated in the scenario.

The prototype was demonstrated to four Army personnel: two commissioned officers and two non-commissioned officers. Their impressions provided feedback that was used to revise the prototype and to make recommendations for future enhancements of the system.

Findings:

To be useful, knowledge network development must be based upon clearly enunciated requirements expressed in terms of the minimum required capabilities. The information engineering activities used in the project ensured that the prototype would focus on the information required to meet mission needs. The prototype system illustrates how mission accomplishment can be supported by information search, retrieval, organization, and dissemination methods.

Several activities should be conducted to foster further development and successful implementation of knowledge network concepts, including the following: (a) focus information engineering efforts on identifying authoritative sources of information, (b) integrate knowledge networks into Future Force command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) networks, (c) complement rather than duplicate the requirements of other Future Force initiatives, (d) ensure that knowledge network tools are adaptable to a wide range of users through intuitive, user-friendly interfaces, and (e) conduct a variety of evaluation efforts at both the component and system levels.

Utilization of Findings:

The results of the research have identified several methods that can be incorporated in existing and future Army knowledge networks. The results of the demonstration provide preliminary evidence regarding the feasibility and acceptability of these methods. These results can benefit personnel in the U.S. Army Training and Doctrine Command (TRADOC), the Unit of Action Maneuver Battle Laboratory (UAMBL), and other agencies involved in the design and development of tools supporting the Future Force.

KNOWLEDGE NETWORKS FOR FUTURE FORCE TRAINING: ILLUSTRATION OF SEARCHING, RETRIEVAL, AND COMMUNICATION CONCEPTS

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Introduction

The U.S. Army is changing the structure and organization of units to produce a lighter, more mobile Future Force that can operate readily within joint and coalition environments. The goal of the transformation is to make the force more responsive, deployable, agile, versatile, lethal, survivable, and sustainable. These characteristics will enable Future Force units to see and understand the environment quickly, act effectively, and finish decisively. The primary Future Force tactical element will be the Unit of Action (UA), roughly equivalent to a brigade of today (U.S. Army Training and Doctrine Command [TRADOC], 2003b).

One key to the success of the Future Force is the ability of units and their commanders to have accurate and timely knowledge about the mission, terrain, status of friendly and enemy combatants, cultural characteristics, weather, and other situational information. The primary asset that will allow Future Force units to achieve information dominance is the command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) network. The C4ISR network will enable Future Force commanders and command groups to receive, process, and transmit information rapidly and to make and adjust decisions on the move. They will use the C4ISR network to plan operations, to control placement and movement of manned and robotic sensing and firing elements, to effect the engagement of targets at extended ranges, and to communicate information and orders.

Other information will be required to provide training and performance support to Future Force units. Much of this information will be available in digital format from any of a variety of private and military databases, file servers, and other electronically linked sites. Using this information, UA elements will be able to practice operations and conduct training even while deploying or deployed, thereby extending staff capabilities. Relevant information may include doctrinal materials, recommendations by subject matter experts (SMEs), intelligence on a particular area or enemy, training materials such as training support packages (TSPs), and tools for tailoring available training materials and operational tactics, techniques, and procedures (TTPs) to meet unit needs (U.S. Army Armor Center [USAARMC], 2003).

Because of the amount of information expected to be available and the number of information sources, obtaining the answer to a specific information requirement (IR) could be a complex process. A search may produce conflicting information from different sources, as well as information with varying degrees of accuracy and recency. The process of formulating a search, reviewing the information obtained, and verifying the relevancy and accuracy of the information could take hours or possibly even days, without any guarantee that the information produced would be completely relevant to the question that prompted the search. Searchers would only know what information was retrieved, not necessarily what other information supporting their IR was available from other sources to which they did not have access.

To meet information needs for UA operations and training, the Army is developing knowledge networks (KNs) that will provide access to information from a wide range of sources

to support the full spectrum of military operations. The KNs incorporate databases that are managed by Army organizations, links to other relevant information sources, advanced search tools, innovative displays, information-sharing capabilities, and other technologies to get relevant information to meet the needs of Soldiers and their units. When deployed with and accessible from Future Combat Systems (FCS), KNs could be key enablers for the Future Force that will allow Soldiers to search for, obtain, and share their knowledge to enhance mission accomplishment.

Critical to the success of knowledge networks within the Army are procedures that will allow a Soldier to access efficiently the information required to perform his or her mission. The procedures must be able to identify authoritative information that is appropriate for the user's function in the unit, for the situation at hand, and for the user's preferences for content and format of that information. In addition, the knowledge network should include procedures that allow the Soldier to add new relevant information and lessons learned to appropriate repositories. Information added to the network could include intelligence gained, lessons learned, and modifications of TTPs or TSPs. Such capabilities have been described as reaching back for and pushing forward information. The general term "reach" is used to describe the capability for multi-directional exchange of knowledge network information (Department of the Army [DA], 2002a).

Project Objectives

The utility of the vast amount of digital information that will become available to Soldiers in the Future Force depends on the development and implementation of procedures to efficiently access, manipulate, and disseminate it. The research described in this report seeks to evaluate the potential of current and emerging technologies for information storage, distribution, and retrieval to support Soldiers in the Future Force who must meet specific IRs or who must communicate to others the information obtained. The overall goal of the effort was to develop a prototype system that illustrates how these technologies could be used to support the information sharing process.

To support the overall goal, it was necessary to understand the information that would be required by the Future Force, to evaluate candidate technologies for managing knowledge networks, to implement promising technologies in a prototype, to evaluate and enhance the prototype, and to document the results and their implications. The following technical objectives specify the project requirements.

- To complete a functional description and design of knowledge networks for Future Force units, with a focus on UA training.
- To develop a prototype knowledge network that illustrates capabilities that can be used to integrate available information to support selected UA training requirements.
- To try out and refine the prototype knowledge network, demonstrating its capabilities for rapid reconfiguration and expansion.
- To document findings along with recommendations for future research and development.

The resulting prototype illustrates the use of technologies incorporating freely available software and a combination of actual and hypothetical data. The hypothetical data represent some of the types of information expected to be available to the Soldier in the Future Force. To provide this illustration within the fiscal constraints of this effort, we could not obtain the most advanced implementations of each relevant technology. Nevertheless, the prototype capabilities provide a concrete example of how these technologies could be used. Concepts included in the prototype could be incorporated into current or planned systems, or could form the basis of a new system. It was not intended that this research would specify how the prototype should be implemented.

Organization of Report

This report continues with an overview of the changes that are encompassed in the transformation to the Future Force, focusing on the need for information that will govern the requirements for future knowledge networks. It then presents a summary of technologies that may help to meet the information needs of the Future Force. Most of these technologies already exist in some form, and allow Internet users to query, search, sort, and disseminate information on the World Wide Web.

The report then describes the procedures that were used to conduct the information engineering and prototype development activities. An analysis of IRs related to the Future Force forms the basis for the design and implementation of the prototype network. We describe the prototype and report the results of a demonstration to Army commissioned and non-commissioned officers (NCOs). Finally, we summarize the results and discuss their implications for future research and the eventual implementation of knowledge networks for the Future Force.

Background

This section begins by describing characteristics of the Future Force that might relate to its information needs. It then describes existing technologies for information retrieval and dissemination that could be the basis of a KN for the Future Force.

Understanding the Future Force

Because the development of concepts of operation for the Future Force and the FCS is ongoing, certain details of UA organization and functions have not yet been specified in planning documents. For example, a review of documentation found limited details regarding staff organization and functions at brigade and battalion levels. Although the Operational and Organizational (O&O) Plan (TRADOC, 2003b) provides details on how the UA staff is organized during combat operations, the staff cell descriptions are at a collective rather than individual level. We anticipate that the inevitable changes in Future Force concepts that will occur as they evolve will have little or no technical impact on this research. However, some of the details of the organizations and operations of the UA mentioned in this report may have been modified by documents that were prepared after the review was completed (approximately June 2003).

Analysis of the O&O Plan, the Operational Requirement Document ([ORD] USAARMC, 2002b) and the System Training Plan ([STRAP] USAARMC, 2003) highlighted the following areas as being central to understanding the Future Force organization and operational concept:

- Developmental Concept,
- Organization,
- Operations,
- C4ISR,
- Training, and
- Information Dominance.

Developmental Concept

The Army currently performs a full spectrum of operations and missions—including peacekeeping, homeland security, security assistance, and ground combat—using combinations of nine ground combat formations. The variety of unit compositions complicates transport, resupply, survivability, and terrain restrictions. The UA will be a flexible unit capable of performing most missions, with the exception of those employing Special Forces (SF), Rangers, or airborne forces (TRADOC, 2003b). The UA is designed to operate alone or as a part of a joint team against any level of threat. The Future Force team must be strategically and operationally responsive, rapidly deployable, and able to change patterns of operations quickly. The forces must have the ability to generate superior combat power by leveraging the synergy of maneuver, firepower, protection, and leadership. They must also be dominant over the enemy, informed by reliable situational awareness and understanding (DA, 2002a).

Organization

The UA is not designed to be a fixed organization. It has the capability to command and control up to six maneuver battalions. The UA will also be able to draw on a range of supporting capabilities from a Unit of Employment (UE) or from the Joint Task Force (JTF) to perform a variety of missions including Psychological Operations and Civil Affairs. As a flexible structure, the UA will be tailorable for specific missions by adding to or changing its capabilities. Its C4ISR architecture will enable the UA to increase its span of control. Maneuver-sustainment support units such as the Forward Support Battalion will also be tailorable with additional capabilities when required to support UA augmentation (TRADOC, 2003b).

Operations

The UA will normally fight under the command and control of a divisional UE (in some situations a Corps/JTF). The UE will employ UAs to achieve tactical objectives. The UA will integrate organic and supporting Intelligence, Surveillance, and Reconnaissance (ISR) fires, and maneuver to close with and destroy the enemy. The FCS ORD (USAARMC, 2002b) lists the required operational capabilities. Several of these requirements are summarized in the following discussion.

Deployability. The UA is designed and will be equipped to support rapid deployment to austere theaters with unimproved entry points, without relying on fixed ports or staging bases. The unit will be able to deploy anywhere in the world within 96 hours of alert. A force as large as five divisions will be available in theater within 30 days of alert. Because of the reduced size and weight of vehicles, compared to existing inventory, the entire unit can be transported by air anywhere in the world. A unit equipped with FCS will be able to use its time en route to rehearse the mission plan (Riggs, 2003). Upon arrival in the area of operations, the UA is designed to be capable of self-sustained operations for three to seven days. Furthermore, it is designed with the durability, endurance, and stamina to fight battles and engagements for the duration of a campaign.

Agility and Versatility. Unit of Action capabilities will permit future commanders to develop plans for meeting a given situation before making contact, to maneuver to positions of advantage and, when ready, to initiate decisive action (TRADOC, 2003b). Forms of maneuver, tactical formations, and movement techniques common to today's force will endure, but the TTP for implementing them will change. The UA will be able to conduct the full spectrum of military operations, including deterrence, homeland security, stability operations, support operations, small-scale contingency (SSC) operations to restore peace and stability, and global war on terrorism. The UA will be optimized for offense in major combat operations (MCO). It is organizationally designed to conduct these operations in all types of terrain and in any weather condition.

Maneuverability. Key factors in maneuverability include decisiveness and the ability to move in both day and night conditions, on all terrain and in all weather conditions, synchronized with Army and Joint fires and ISR. Other capabilities to consider include mobility and the conduct of integrated combined operations to include diverse areas such as urban terrain. Another factor in optimum maneuverability is effective C4ISR support throughout.

Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR)

To accomplish its mission, and to handle the transitions in this type of warfare and retain the necessary momentum and initiative, the UA will need superior situational understanding (TRADOC, 2003b). A key to Future Force units achieving information dominance will be the C4ISR network. This network will enable Future Force commanders, command groups, and their staffs to receive, process, and transmit information rapidly to make and adjust decisions on the move.

The communications provided to the UA will enable it to link into the Global Information Grid (GIG) at any time to include a reach capability for a wide range of data and information (TRADOC, 2003a). The GIG is a globally interconnected set of information capabilities and processes and includes all owned and leased communications and computing systems and services, software, data, security services, and other associated services necessary to achieve information superiority (IS).

Battle Command on the Move (BCOTM) is a key capability contributing to agility and versatility. The Battle Command system represents the migration of all fielded and developmental Army command and control systems into one fully integrated and interoperable system with seamless connectivity from the National Command Authority (NCA) to the foxhole. It will allow commanders in the UA to access information and decision-making tools and to communicate decisions much faster than today. Widely distributed operations on future battlefields will require significantly increased deployability of command and control functions. The BCOTM will be accessible from anywhere on the battlefield, making it possible for a much smaller and more mobile unit to perform the functions formerly originating at command posts (DA, 2002a; TRADOC, 2003a).

Training

Training of Future Force Soldiers and units will be supported by the use of embedded training and electronic centrally distributed training products. The vision for Future Force training is to provide embedded training down to system level (USAARMC, 2003). Command post exercises and command field exercises (CPX/CFX) will be driven by prepared scenarios available for use before, during, and after deployments. Additionally, the systems will be used to embed operations order (OPORD) data that facilitate rehearsals. Another factor that must be considered is that the training materials are developed and made available to UA units by Army training developers (DA, 2003).

Networkable, Reconfigurable, Full Task Trainers (NRFTT). The NRFTT for the FCS family of systems will be devices used mainly at institutions where, depending on class size and student throughput requirements, a training device is more cost effective than platforms and thus can be more available than platforms with embedded training systems. However, the NRFTT and embedded training share the several qualities. The NRFTT, like platform embedded training, will provide a virtual training capability to support individual, crew, and small unit competencies when parts of the combined arms team are not available. The NRFTT will be fully operational without the need for external components to transport or install on the FCS platforms. The NRFTT will be capable of supporting training at individual through brigade levels, and will be capable of simulating and stimulating tactical systems at all echelons. To ensure that training in the NRFTT is the same as embedded training on the platform, the NRFTT will operate with the same software used in the operational/embedded training system and present the same man-machine interface to the Soldier (TRADOC, 2003b; USAARMC, 2003).

Training Distribution System. The FCS ORD envisions an information system down to the battalion nodes and all FCS manned systems, including the individual Soldier (USAARMC, 2002b). The system will provide integration across the spectrum, in a secure mode for planning and rehearsal of missions, from alert to employment. The requirements for the UA training system include the embedded Tactical Engagement Simulation System (TESS), which covers live, constructive, and virtual training methods. The ORD states that the FCS will have an "on-board" repository of technical manuals (TMs), TTP documents, field manuals (FMs), training plans (TPs), and TSPs, interactive multimedia instruction and courseware, and collective training information. The ORD details plans for 24/7 support from the centralized sources for scenarios

tailorable to the unit Mission Essential Task List (METL), to include Computer Generated Forces (CGF). The plan calls for fielding a complete set of TSPs.

Information Dominance

Information operations are so critical to the Future Force that the UA staff will have a dedicated IS cell. Key features that contribute to gaining information dominance include:

- Tactical Database.
- Common Operational Picture (COP).
- Home Station Operations Center (HSOC).
- Command Information System (CIS).

Tactical Data and Common Operational Picture (COP). The Distributed Information Database (DIDb) will provide users a shared awareness of key battlefield information. Access to the DIDb will be available to all echelons of the UA. Through a constant push and pull of information, the DIDb will fuse information from multiple sources to produce the COP. It will also enable access and distribution of information throughout the force in standardized formats. The databases will support a two-way collaborative process in which lessons learned are incorporated into the database (TRADOC, 2003b).

Home Station Operations Center (HSOC). Installation HSOC will enable distributed information sharing among the sustaining base and deployed forces during all phases of an operation. Before deployment, these fixed facilities can collect and process large volumes of data, such as terrain mapping and common databases that must be pre-loaded down to platform level prior to deployment. The HSOC will be the focal point for the synchronization of all training resources required for the execution of training tasks at all affiliated locations.

Communication Information System (CIS). The CIS in the UA will consist of the infrastructure, organization, personnel, and components that collect, process, transmit, and disseminate information. It will enable the commander to view and understand his battle space, communicate his intent, lead his forces, and disseminate pertinent information throughout the UA. This collaboration feature will be key to shortening the normal decision cycle. The CIS will permit continuous fusing, monitoring, and dissemination of information from a variety of sources, through an uninterrupted, robust, multi-layered communications system (U.S. Army Future Combat Systems Program Office, 2002).

Information Technology for Knowledge Networks

As the previous discussion indicates, the UA will operate in an environment characterized by an abundance of information from multiple sources. Some of these sources will be interoperable with UA systems by design, but others will use a variety of processes and data formats. Soldiers in the Future Force will need to search data from a variety of sources and quickly identify and retrieve the most relevant, timely, and accurate information that relates to a particular IR. The information must be provided to them in a format that they can easily

understand and incorporate in their plans. They may also need to share this information with others and to incorporate new information that others can access at a later date.

A knowledge network combines repositories of information with methods to organize, search, retrieve, share, and update the information in the repositories. It provides a common interface to knowledge that may be contained in multiple systems and stored in a variety of formats. The KN must include sophisticated methods for retrieving useful information in a usable format. It must support collaboration among people using different and perhaps incompatible information platforms. Finally, it must support dissemination of information as well as retrieval. If successfully implemented, KNs can provide user-friendly access to vast repositories of existing information (and data) to UA elements involved in Future Force training. They will make it possible to query and search these sources in a timely and efficient manner and to rank and present the most relevant results to the user.

Data, Information, and Knowledge Systems

Implicit in the term, knowledge network is the notion that what is provided by a knowledge system to its user is somehow enhanced or qualitatively different from what is provided by a database or information system. The terms data, information, and knowledge are often used interchangeably, or one is defined in terms of the other. Figure 1 shows what is commonly referred to as the Cognitive Hierarchy (DA, 1999) in order to distinguish among these terms. This pyramid is typically used by organizations in the corporate world, the military, and others to describe the process in which knowledge and understanding are preceded by the existence of data and information.

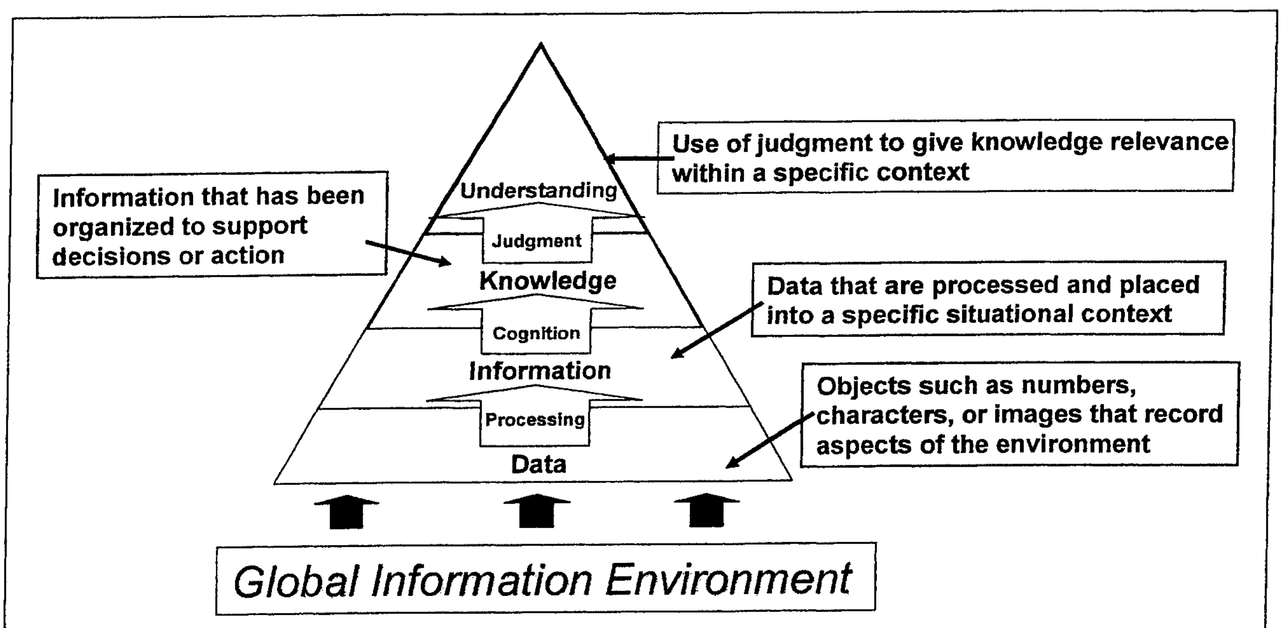

Figure 1. Cognitive hierarchy.

The term, data, represents the most concrete representation of aspects of the environment in a format that can be processed by a human or a machine, and that can be transmitted on some

communication channel. Individual data elements have no meaning in themselves; it is only by processing that data can be interpreted and the meaning understood. In transforming data to information, the elements are placed into situational contexts or categories that allow them to be interpreted. For example, a number such as 324.2 has no meaning in itself. However, if it is known that the number represents a weight, a distance, or a bank balance, then the context provides meaning to the number, which may then be viewed as information. Knowledge requires further processing to combine information from different sources and place it in a format that supports decision-making and action. In addition, knowledge is generative, in that a person's knowledge includes rules that can be used to create new knowledge from existing knowledge or information. Finally, understanding requires additional processing of knowledge to give it relevance within a given context.

These terms may often be confused, and the point could be made that many so-called information retrieval systems should be more appropriately labeled as data retrieval systems (van Rijsbergen, 1979). Table 1 shows the comparison of attributes of a data retrieval system compared to those of an information retrieval system. As the table indicates, information retrieval is a much more difficult task than data retrieval. Data retrieval typically requires simple retrieval rules with easily specified matching criteria. Concepts for information retrieval are often more difficult to define. They may be probabilistic, so that it is not known for certain whether a particular piece of information matches the conditions of a query. Distinctions between similar concepts may not be absolute, and different information elements may partially match several apparently distinct concepts.

Table 1

Data versus Information Retrieval (van Rijsbergen, 1979)

Function	Data Retrieval Characteristic	Information Retrieval Characteristic
Matching	*Exact Match*	*Partial Match; Best Match*
Inference	*Deduction*	*Induction*
Model	*Deterministic*	*Probabilistic*
Classification	*Monothetic*	*Polythetic*
Query Language	*Artificial*	*Natural*
Query Specification	*Complete*	*Incomplete*
Items Wanted	*Matching*	*Relevant*
Error Response	*Sensitive*	*Insensitive*

Knowledge networks expedite the acquisition of data and information and create conditions that speed the development of knowledge and understanding, and hence produce more efficient and effective decision-making. While there may be situations in which it could be said that a KN retrieves knowledge, in the vast majority of cases it is more accurate to say that a KN

retrieves data and information in a way that facilitates the construction and utilization of knowledge. In order to facilitate knowledge generation, the KN must identify the most relevant information, organize it in a way that supports decision-making and action, and present it to the user in a fashion that communicates both the relevance of information elements and their interrelationships.

Overview of Technologies for Performing Network Searches

A typical information retrieval model is presented in Figure 2. This model will serve as a template for those areas that were investigated in this project to determine the state of the art of information retrieval technologies. It is necessary to determine whether the maturity of each will be sufficient to meet Future Force training requirements. The model shows two views into the overall system:

1. The view of the database manager, who is responsible for locating relevant data sources and transforming the text into an index that accommodates quick searches of large volumes of data.
2. The view of the user, who must be provided an interface into the system and given the means to construct a search query. The retrieved data should then be ranked and presented to the user in the most effective manner.

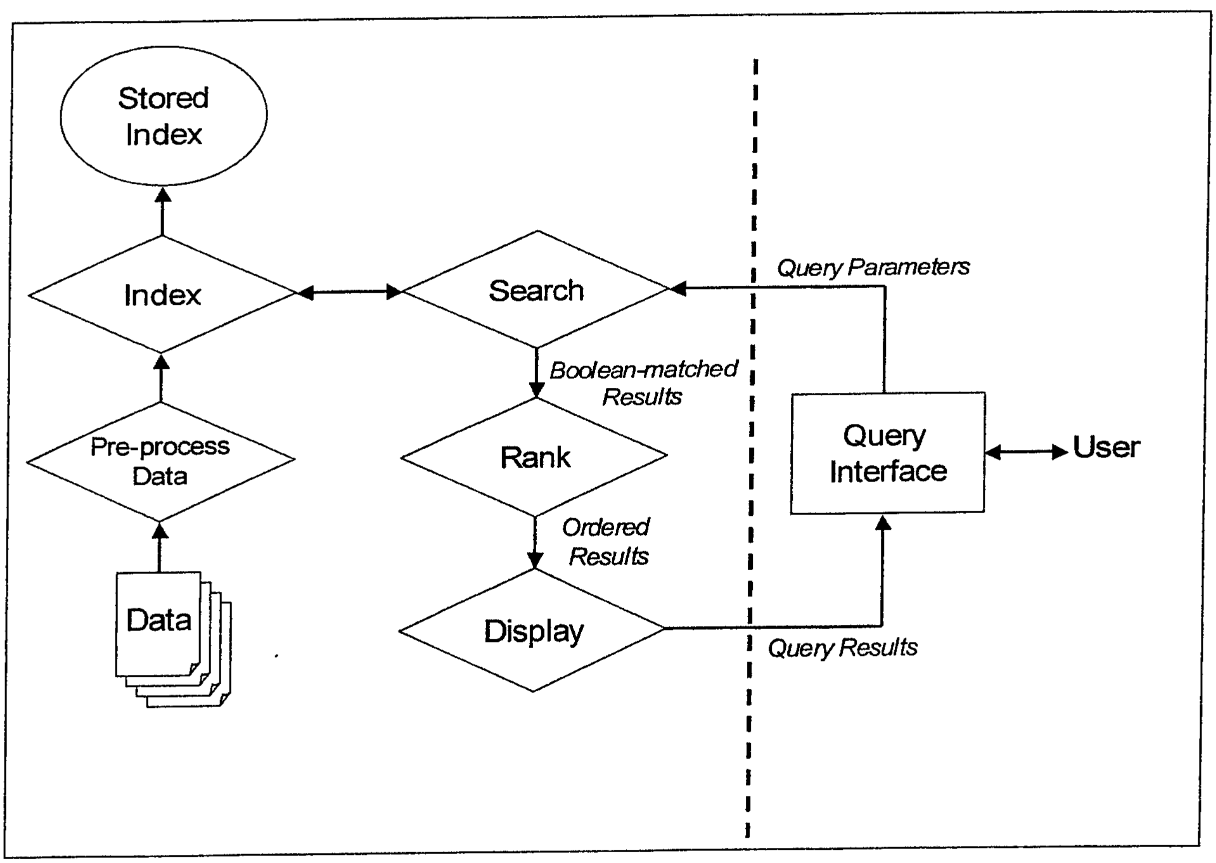

Figure 2. Information retrieval model.

In general, Web-based search engines are derived from a standard architecture (Figure 3). Each has its own unique features, but their overall organizations are the same. These engines are composed of the following primary components:

- Crawlers that traverse the Web looking for new pages and updates to existing cached pages. Cached pages refer to those Web pages retrieved previously from the network and stored locally for more convenient (and quicker) access.
- A method of understanding different file format types (Hypertext Markup Language [HTML], Postscript [PS], Portable Document Format [PDF], etc.) and converting them into a single understandable format (i.e. flat text).
- An index to store a lexicon of keywords used by crawlers to identify relevant documents, their location within a particular document, and other specific details about word occurrences.
- A means for users to query the index for matching results.
- A means to rank/sort the results returned from a query.

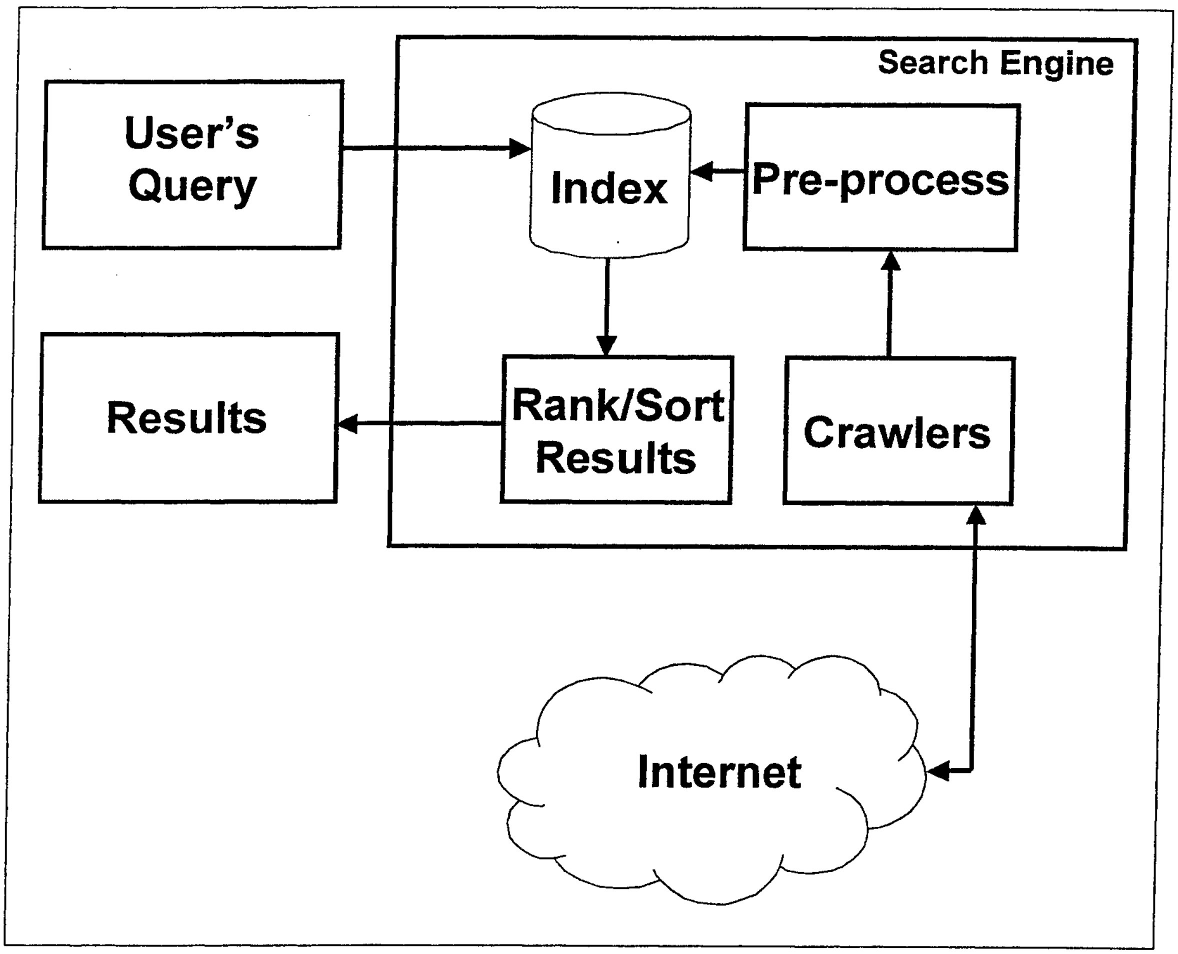

Figure 3. Standard search engine structure.

Typical search engines have crawlers continually traversing the Web looking for new pages not yet indexed and updates to pages that are cached and have already been incorporated into the index. Once found, these documents must be processed and stored for future use. This processing involves several steps. First the documents must be converted to a common format that is understandable by the system (usually flat text). Documents of different formats (Microsoft Word and PowerPoint, PDF, HTML, etc.) must all be converted into this common format so they can be processed and analyzed. Then the document must be parsed and the keywords extracted. There are different algorithms for doing this, but in general all of the "stop" words (common words such as "the," "and," "for," etc.) must be removed from the document and then the remaining words are stemmed (reducing a word to its root form). There are many different stemming algorithms, but the most popular by far is the Porter Stemmer (Porter, 1980). The Porter Stemmer uses a set of rules to automatically remove different suffixes within words to reduce them to their root forms. For example, the words *connected, connecting, connection,* and *connections* would all be reduced to the base *connect.* Through the removal of "stop" words and the execution of the stemming process, the set of terms that must be processed within a document is greatly reduced. In addition, this process results in an overall smaller index and therefore speeds up queries by reducing the number of terms that must be evaluated when executing a search. In addition, the smaller index takes up less memory and becomes more manageable.

The documents must be cached so the index can periodically be updated as new pages are found. For example, Google™ rebuilds its index monthly, on average, and each update usually takes several days to complete. If an index is large, such as Google's, updating can be complex, balancing the need to keep the old index accessible while the new index is being generated. Once the indexing update is complete, the new documents are incorporated into the new index and the engine points users to the new index. The Internet is a dynamic structure, with search engines continuously locating new information, rebuilding and updating the index, and making it accessible to users.

Useful search engines and the indexes behind them must be accessible to users. Typical Web-based engines perform full-text keyword-based searches in which a user enters a set of keywords into the search box, and the engine returns all pages matching the query. The engine must take these keywords and evaluate the index, returning all those sources that match the query. If a simple, conjunctive Boolean-based search were used, then every document containing all of the words entered would get returned. For efficiency, the engine checks the index and looks at the number of documents that are associated with each word entered into the query. It then selects the smallest document list to start the process. Since queries are generally conjunctive, all words that appear in the query must appear within the document, so the list returned to the user will at most be the size of the smallest list. This list is then intersected with the document lists for all the other words contained in the query. Finally, a set of documents that incorporate all the words entered is returned. As one would imagine, this could be quite a time-consuming process as the document lists become larger. Different algorithms have been developed to help speed up this processing by compressing the manner in which indexes are stored, using hashing techniques to speed up the process of searching, and so forth (Witten, Moffatt, & Bell, 1999).

To make search engines more usable, they typically have some means of ordering the results before they are presented to the user. This allows the engines to rank items by their estimated relevance, reducing the need for the user to look at many irrelevant documents before the sought after information is found. Ranking algorithms come in many different forms. They can look at different characteristics of the page, such as frequency counts of words and how and where the keywords get used within the page (how many times a keyword gets used, is it in a heading, is it bold or italicized, etc.; Brin & Page, 1998). Google™ incorporates many of these ideas to achieve its page rankings.

One of the most popular page-ranking algorithms, called PageRank, calculates an "importance value" for a page based on the number of links from other pages pointing to the page. Highly linked pages are considered to be more important than pages linked from only a few others. The system also weights the page's importance based on the ranking of the pages pointing to it. This calculation may present a problem because we will not know what ranking those pages have until the pages pointing to them have their rank calculated and so on. PageRank solves this problem by using a simple iterative algorithm (Page, Brin, Motwani, & Winograd, 1998).

Google's PageRank provides fairly high quality search results; however, important pages mean nothing to a user if they don't match his or her query. Therefore, Google™ combines PageRank with sophisticated text-matching techniques to find pages that are both important and relevant to a query. Google™ goes far beyond counting the number of occurrences of a term per page and examines all aspects of the page's content (and the content of the pages linking to it) to determine if a page is a good match (Brin & Page, 1998). It evaluates where the search terms appear within the document and categorizes the term's appearances into one of several categories (i.e., title, anchor, uniform resource locator [URL], plain text, etc.). Finally, it calculates a score for the page based on where the words appear.

Although current Web search tools provide a more efficient way to gather information as compared to manual alternatives, easier and more intuitive ways to gather information need to be investigated. By applying various emerging technologies, such as Bayesian and vector indexing, to the standard search process and allowing a user to obtain and digest information more easily, knowledge and understanding can be acquired more efficiently. Gained knowledge and understanding then become the basis for sound decision-making.

Other Means of Information Distribution

Users want easier, more automated access to information without the need to have to go out and pull it down. With many of the new technologies available on the Web, users can log on to a system and instantly be alerted that new information that affects them or their work is available for downloading. Two popular forms of communicating information across the Web that are currently being used are blogs (short for Web Logs) and rich site summary (RSS) news feeds.

Web logs. Blogs are emerging tools that take advantage of some of the major features that the Internet provides (Siemens, 2002). Blogs support knowledge sharing and

communication by allowing information to be published. In general, blogs contain dated entries in which a user can post some piece of information. Once the information has been posted, others can read and comment back to the originator. These comments are visible by all and many times online discussions can be started. These blogs can be used in many different ways to support knowledge sharing and knowledge network management, learning, and experience tracking. For example, deployed troops could post information about current conditions in the field and make equipment recommendations that could be available to units that are in the pre-deployment phase. This could provide valuable information sharing that might never happen otherwise.

Rich Site Summary news feeds. Another form of information sharing is the RSS format. The RSS is an extensible markup language (XML)-based format that describes the metadata about a Web site and has become a popular method of distributing news headlines on the Web (Lewin, 2000). Currently, RSS feeds are most prominently used by news organizations and Web sites for distributing headlines, but are also being used by smaller organizations to alert subscribers to the availability of new information or updates to existing information. The RSS feeds could easily be used to distribute both horizontally and vertically within military organizations. A user would simply have to subscribe to an information channel that distributes a feed of interest, and as updates become available, the user would be alerted automatically. These feeds allow for easy information push without the need for the user to check for updates on multiple sites.

Formatting Knowledge for User Needs

Portal-style Web pages, sites that collect a selection of services and resources into a single location (such as Yahoo.com's main page); have become quite popular by providing a user with a structured and customizable display of information. User profiling and agent technology provide other methods to provide information that specifically meets a user's needs in a format that the user prefers.

Portal interfaces. A popular means of structuring information on the Web is through the use of portal-style interfaces. Portals are standard, frequently used Web sites that offer a user a variety of services and resources collected into a single location (Levine, 2002). One of the most popular examples of a portal is the Yahoo!® main page (www.yahoo.com). This page provides the user with many different types of information, links to various types of services, and is simple to use and understand. Portals are not limited to public sites and can be used within business Intranets to allow easy access to tools and information for users. Using a common framework for information sharing and access, the portal allows the organization to integrate different technologies into a common framework. The ultimate goal of portals is to offer the user easy access to a range of information and resources with a single click of the mouse. Portal sites should be very well organized and possibly even customizable by the user. For example, if news headlines from different sources were displayed, then the user should have the ability to select what sources get used and what types of articles get returned. Ideally, each user could set up his own set of links to preferred pages through customization of the portal page.

User profiling. The concept of tailoring information to a user's interests or needs is a developing technology slowly moving into the mainstream in extending access to information storage and retrieval. Numerous current academic projects are researching different profiling methods. Some store on a user's machine informational "cookies" that capture details about sites the user visits. From the collected data, the researchers attempt to predict users' interests for ads and headlines. Others use machine-learning and data-mining techniques to help rank the pages returned by a search. The use of intelligent agents (semi-autonomous computer programs capable of carrying out one or more tasks specified by the user) for dynamic information searches is growing in popularity. There are many different focuses within these research projects, but the common goal is to make searching for and obtaining information an easier process.

Profiling a user and tailoring information based on known interests and behaviors is an active area of research. Currently, some sites such as Amazon.com and Yahoo.com attempt to profile users by storing information about the sites they visit or products they review and then display ads or products that are representative of those interests in the hopes that a user will be attracted to a particular product. However, these profilers are somewhat simplistic.

More sophisticated user profilers being developed as part of current research projects far surpass the approaches used by Amazon.com and Yahoo.com. These projects are developing more advanced techniques for categorizing information content and personalizing information ratings based on user interest categories. One such system is Alipes, a personalized newsagent that gathers articles periodically from various online news sources and filters them on behalf of a user's interests (Widyantoro, Yin, et al., 1999). In Alipes, a user profile is represented by three descriptors: a positive descriptor, a negative descriptor, and a long-term descriptor. The positive and negative descriptors represent a user's short-term interests (which could drastically change over a short period of time) and the long-term descriptor represents a user's relatively stable interests (Widyantoro, Ioerger, & Yen, 1999). Hence, Alipes is able to adapt to the dynamic nature of a user's interests, which may change slowly or very suddenly over a varying period of time and continually recommend interesting articles to the user (Widyantoro, Ioerger, & Yen, 2001). Alipes has been demonstrated to be quite effective at ranking news sources with respect to a user's interests.

Agent technology. Another technology of potential use in constructing knowledge networks is the use of agents for locating and filtering information before it is presented to the user. One example is Constructing Intelligent Agents (CIAgent), a system developed as part of IBM's Agent Building and Learning Environment (ABLE). It is an agent-based framework for creating and using user profilers (Bigus, 2001). The CIAgent is able to function as a personal assistant, an information filter, and a market buyer or seller. The CIAgent filters news based on a set of user-provided keywords. A user's profile evolves over time by using alternative modeling algorithms referred to as self-organized maps and neural networks.

Another area of information retrieval research is focused on how agents can be used in the process of information fusion. Agents can collect diverse information from multiple sources and merge it into a single representation to be presented to the user. For example, a user could tell his agent that he wants to go on a date and see a particular movie around 8 P.M. on Friday

night. The agent could then find the times from various theaters near the individual's home, locate restaurants near the theater that the agent determines the user would like (based on known user preferences), generate maps to the various locations, and fuse them into a common map. The use of these types of agents would eliminate the need for a user to go out and individually locate each of these pieces of information.

As the technologies used for information storage and retrieval continue to improve, the Future Force could apply many of them to developing knowledge networks. The prototype developed under the auspices of this research incorporates a representative sample of such technologies.

Summary of Development Activities

This research began with a comprehensive analysis to identify and organize IRs for specified UA functions. With the information gathered, we constructed a matrix that associated IRs with tasks, enabling us to construct a scenario that would stimulate Soldier queries for a variety of information. Based on this scenario, we designed, developed, and demonstrated a prototype knowledge network.

Information Engineering

We used information-engineering processes to identify the IRs for a given organization. Based on these requirements, we defined the set of system capabilities needed to identify and locate that information. We tailored the information engineering process, consisting of the following steps, to reflect the nature of the UA.

1. *Define the Organization.* We characterized the UA, including staff, suborganizations and significant variations.
2. *Acquire Knowledge.* The research team identified organizational missions, tasks, functions, personnel, equipment types, capabilities, and conditions for employment, including tactical operations and command and control relationships. For the Future Force, this required the study of a range of documents that change frequently such as the O&O Plan, the ORD, the STRAP, and applicable white papers. In addition, we reviewed references applicable to similar organizations in the current or more near-term force. These included the Army Universal Task List ([AUTL] TRADOC, 1999), Combined Joint Task List ([CJTL] Chairman of the Joint Chiefs of Staff [CJCS], 2002), FM, and Mission Training Plans (MTP). Because many of these references have not yet been published for the Future Force, extrapolation from current procedures and tasks provided a credible, "best available" set of unit tasks.
3. *Develop a Flowchart.* We designed a detailed flowchart of activities proceeding from organizational baseline specifications to compilation of a desired set of IR. Baseline points of derivation included structure, concept for use, performance tasks and internal and external relationships.
4. *Map Tasks to Functions.* We selected specific organizational functions and mapped out tasks required to perform those functions. Various missions were evaluated in a

manner similar to the way the AUTL (TRADOC, 1999) maps tasks and sub-tasks. We selected the task of *deploy to a tactical area of operations* and tracked all the tasks and sub-tasks supporting the preparation, planning, deployment and employment of the UA. We built a matrix to organize the data, thereby facilitating subsequent retrieval and use.

5. *Synthesize Information Requirements*. We developed an association from functions and tasks to applicable IRs. We noted probable sources of information to meet the IRs, if they were known. For each IR, we noted whether the information needs were to be shared with other units.
6. *Put Information Requirements into Categories.* We analyzed the IRs and identified significant groupings or categories into which they could be sorted to expedite information source indexing. Some categories were very specific, such as "logistics," "plans," and "maneuver;" others were collapsed into a more general category such as "operations." When the results were used to design an information gathering system, they were earmarked by group to determine sources of information or to express a capability requirement.
7. *Develop Search Queries.* We developed a list of queries appropriate for use in the target information gathering system, which also resulted in a "key word" listing.
8. *Validate IRs and Queries*. We validated the results by selecting representative samples of the IR lists across functional areas and conducting searches using a variety of search engines or a prototype advanced search tool if one was in production. For the Future Force, which will not be operational for ten years or so, such data did not exist. In this case representative or substitute information was developed for incorporation in prototype databases.
9. *Enumerate Required Capabilities*. We converted the validated set of IRs into a list enumerating the capabilities required for a knowledge network intended to gather user requirements. Enumeration was done at several levels of detail. A more general enumeration identified capabilities at a higher level such as "*Support Military Decision-making Process*." A more detailed list included specific needs such as "*Retrieve all applicable mission OPLANS and OPORDS for higher, lower and lateral units*."

The objective of the information engineering was to combine the entire organization, a suborganization, and the various individual staff members and commanders within that organization. The engineering process was used to identify the specific IRs, based on the mission tasks, operational concept, organizational structure, and functional relationships.

Figure 4 diagrams how the data and information in these four areas flow into a series of analytical steps and ultimately a specified set of IRs. These activities identify common categories of information relative to a combat unit. Some modifications were made as applicable for maneuver support or other type units. Note that the process diagram accounts for selection of a desired set of tasks or functions from which to derive IRs. A select cross-section of tasks was identified to use in the prototype to represent the overall unit. One aspect that must be considered when analyzing large organizations such as a brigade is that there are multiple

suborganizations. We had to choose whether to drill down to each level or to examine the organization from an aggregated perspective. In this project, the UA was analyzed as an aggregate for all functions with the exception of training. The figure illustrates this separation of the training function. Training was analyzed from brigade staff down to individual Soldiers. The other functions, such as Intelligence, were aggregated at the brigade staff level.

Initially, the engineering effort addressed the unit IRs on a broad front, but eventually a set of battlefield functional areas (BFA), tasks, and activities were selected as indicated in the process schema (Figure 4). We examined all identified IRs to determine if there were any prevalent grouping based on source or similarity of activity. Two groups of IRs fell out as clearly significant: training and operations. Both of these areas have well established procedures and documentation that justify some form of special designation and treatment when designing information search tools. A third and more broad area of IRs, designated simply as "General," covers all other information needs. These three IR types were identified to the technical developers of the knowledge network prototype as potential search index categories and search paths and for consideration in designing user interface windows (right side of the flowchart).

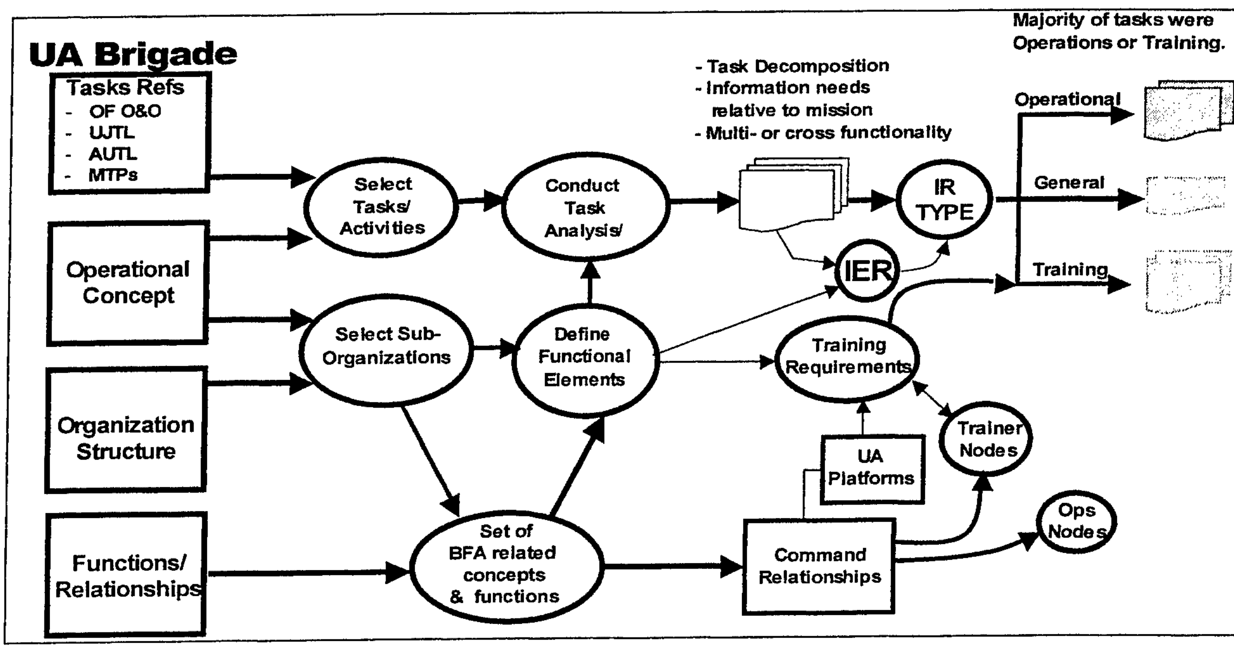

Figure 4. Information engineering schema for prototype Knowledge Network.

Scenario Driver

As noted previously, the full set of tasks performed by a UA was pared down to a workable set that could be examined for mapping IRs to information network capabilities. A practical method to construct this mapping was to use a hypothetical set of conditions into which the unit was placed to stimulate various actions and reactions. The scenario selected for use in this research was based upon Future Force Mission Thread 1 (USAARMC, 2002a), similar to Future Force O&O Vignette 1 (Annex F) (USAARMC, 2003). The scenario envisioned the alert of a UA Brigade to deploy from its home station to a tactical operations area within 96 hours.

The use of a scenario driver in the information engineering process stimulated specificity in the tasks required to carry out the mission(s). Figure 5 graphically portrays how the process led to identification of IRs by type, the conversion of IRs to queries to be used on the knowledge network, and receipt of the search results. The process chart includes a subroutine that parses the IR into three basic categories of information (training, operations and general). It also includes the provision for sharing information with other members of the subject unit or other units.

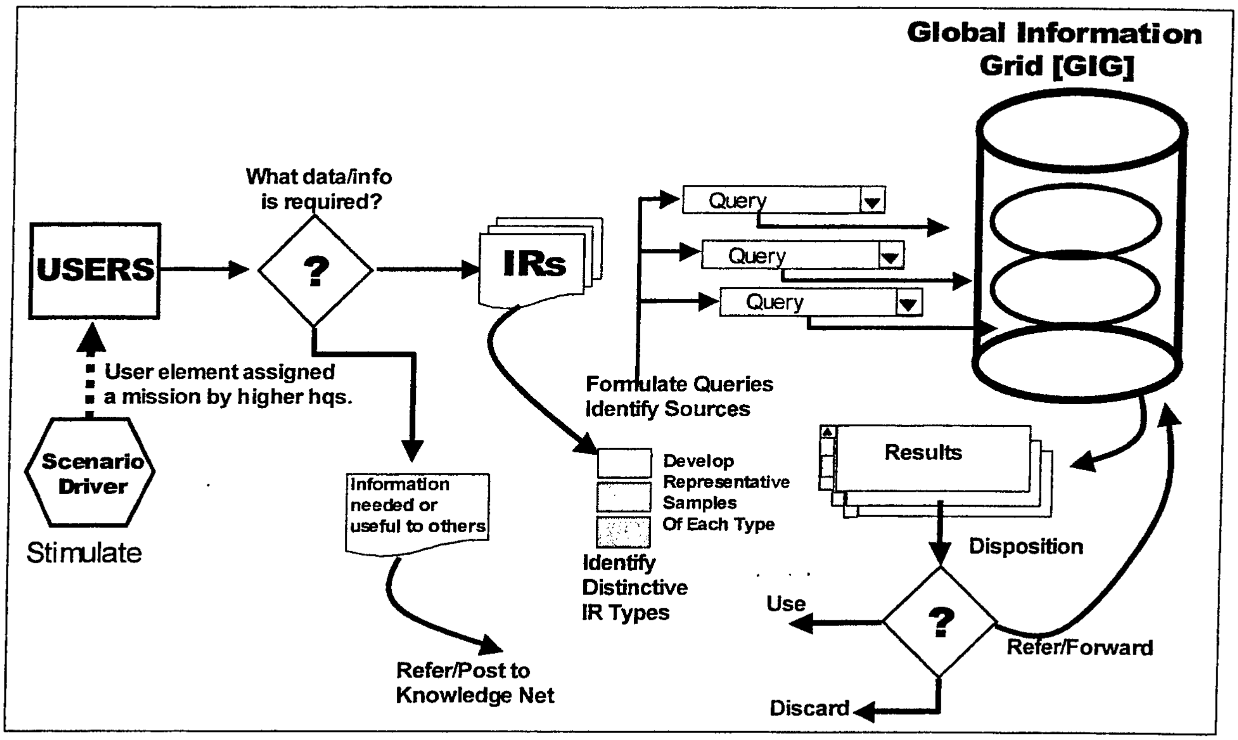

Figure 5. Information engineering—scenario driver.

We used the scenario driver to identify select IRs and develop queries through the following five steps.

1. We established a set of hypothetical users.
2. We stimulated a given set of users with the introduction of a feasible scenario that activated staffs and commanders toward a set of plan, prepare, and execute actions.
3. We developed a set of IRs based on analysis of the user unit mission and the data and/or information required to accomplish it.
4. We discovered many pieces of information during the task analysis process that were of possible use to others.
5. We classified IRs by distinctive types and probable sources.

We began this process by interjecting scenario variables such as mission, region, and command and control (left side of Figure 5). We studied selected BFAs by functions that aligned with a set of tasks. In turn, we examined each task to extrapolate what information was

needed for its successful completion. Then we categorized the IR, after which each task was mapped to a stated query for the search tool, which in turn implied a required information gathering capability. These implied capabilities were synthesized and grouped prior to conversion to specific capabilities. The point of the capability mapping was to identify the specific capabilities needed to design a knowledge network for a UA.

Unit of Action—Tasks and Functions Analysis. The UA command and staff functions were defined in terms of the basic organization and the BFAs that are foreseen for the Future Force. The Future Force O&O Plan for Maneuver UA (TRADOC, 2003b) provides some detail on how the UA staff and subordinate units are to be organized and equipped. The BFAs do not provide the level of specificity needed for a detailed analysis. A parallel analysis was made, therefore, using O&O and current staff subfunctions and the AUTL (TRADOC, 1999). One can use task lists such as the AUTL and Universal Joint Task List (UJTL) by taking a set of tasks, estimating the applicable function(s) required to perform them, and generalizing to analogous future tasks.

Functions Table. The baseline from which we derived the Future Force unit IRs consisted of a combination of functions and tasks from both the projected UA Brigade function and the way command and staff operates today. Table 2 illustrates this blend.

The UA Brigade will operate in a joint environment. Joint interoperability requires that even functional tasks be translatable into common joint terms as expressed in the UJTL (CJCS, 2002). Table 3 correlates the joint tasks to the Army BFA or concepts used in Table 2 (TRADOC, 2003b).

Research of current doctrine identified a relatively large number of sub-functional areas associated with the current AUTL and other formal task listings (left side of Table 2). The AUTL and MTPs do not yet exist for the UA. Given some modification and simplification of functions between current staffs and Future Force staffs, we found sufficient basis for determining IRs when using a specific scenario for employment of the UA. We constructed a matrix to facilitate the identification of IRs relative to specific BFAs and unit functions (illustrated in Figure 6). As depicted, the analysis can focus on one organizational level (brigade) or address multi-levels (brigade, battalion, company [USAARMC, 1998, 1999]).

Capabilities Mapping

Mapping is essentially a sub-process that parallels identification of information needs for a given organization, expressing IRs in terms of both general and specific individual or collective actions. For example, the general capability of the individual or staff to "plan" can also be expressed in a set of more specific capabilities (TRADOC, 1999), such as "to receive and distribute Operation Plans (OPLAN) and OPORD vertically and horizontally in the chain of operational command" and "obtain higher headquarter Priority Intelligence Requirement (PIR)" (DA, 2001a).

Table 2

Functions Baseline

Current Areas and Functions			Future Force Areas and Functions	
Battlefield Functional Areas	Staff Functions		Battlefield Functional Areas	Staff Functions
Command and Control	Command Posts Signal Support Plan and Prepare Execute Operations Maintain		Battle Command	Plans Synchronize Operations Track Battles Maintain COP Synchronize C4ISR Liaison
Intelligence Communications	Combat Intelligence Counter Intelligence Weather Psychological Operations (PSYOPS) Information Warfare		ISR	Manage Knowledge Network Base Functions Collect Intelligence Oversee All Intelligence Refine Threat Picture Analyze Battle Space Support Targeting
Operations & Maneuver	Deploy Ground Maneuver Aviation Security	Plan Operations Plan electronic warfare	Maneuver	Track Operating Areas and Airspace Supervise Deployment Identify Maneuver Options Control Maneuvers
Fire Support	Precision Indirect Area Fires General Attack Helicopter Naval Gunfire Close Air		Fires	Select Targets Collaborate on intelligence preparation of the battlefield Direct Counter-Fire Clear Fires Electronic Warfare
Mobility & Survivability Air Defense	Air Defense Nuclear, Biological and Chemical (NBC) Combat Engineer Construction Bridging	CMO Military Police Civil Affairs Pipeline Protection	Maneuver Support	Traffic CMO, Civil Affairs Population Control Intra-Theater Movement
Logistics Personnel	Personnel Management Medical Welfare/Morale Public Affairs Office Chaplain Postal Base Facilities & Utilities	Recreation Graves Registration Finance & Legal Safety Supply & Maintenance Transport Rear Operations Water Purification	Maneuver Sustainment	Support Plans Pulse Re-supply Provide Health Services Support Soldiers Manage Human Resources Provide Religious Support
NA	Training Schoolhouse		Soldier	Provide Training Develop Leaders

Table 3

Correspondence of Unit of Action (UA) Tactical Concepts to Universal Joint Task List (UJTL) Tactical Tasks

Tactical Concepts	UJTL Tactical Tasks
Battle Command	TA 5 Exercise Command and Control
Intelligence, Surveillance, and Reconnaissance (ISR)	TA 2 Develop Intelligence
Maneuver	TA 1 Deploy/Conduct Maneuver
Fires	TA 3 Employ Firepower
Maneuver Support	TA 1 Deploy/Conduct Maneuver
	TA 6 Protect the Force
	TA 7 Operate in Chemical, Biological, Radiological, or Nuclear (CBRN) Environment
Maneuver Sustainment	TA 4 Perform Logistics and Combat Service Support

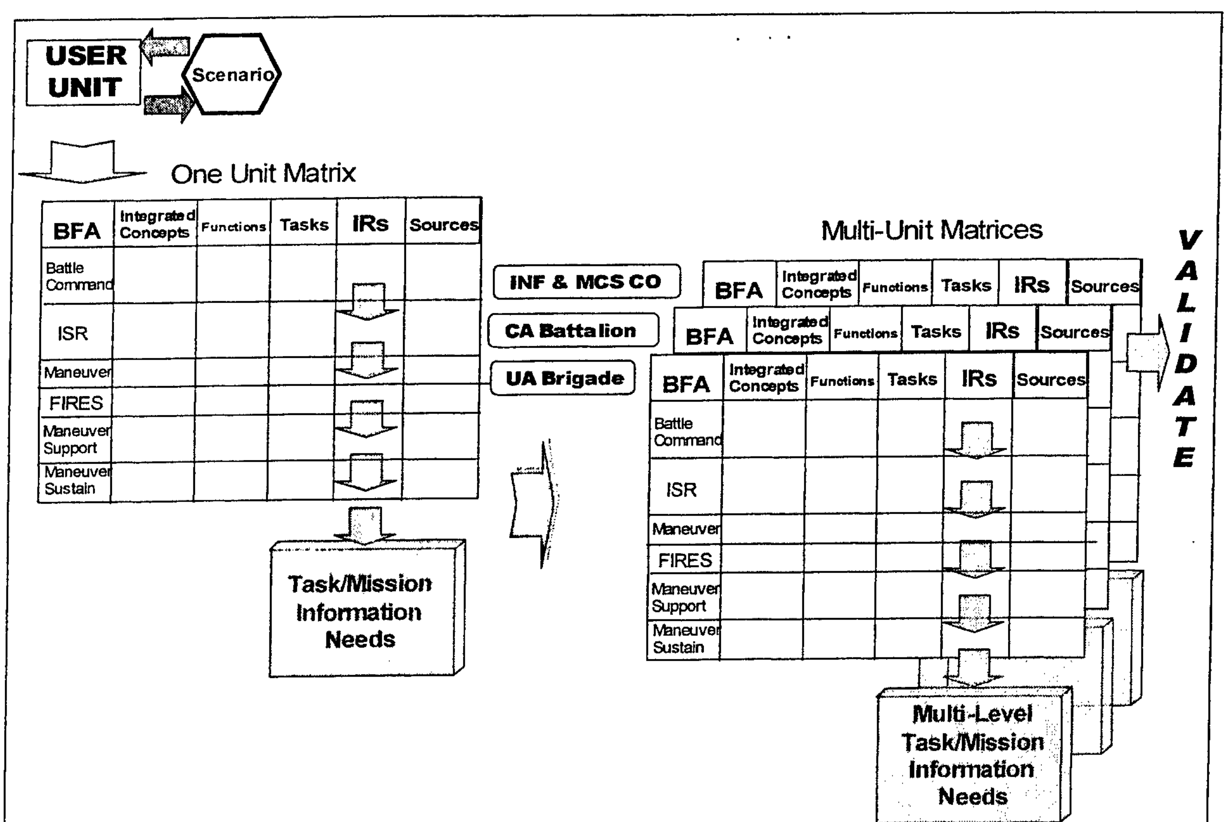

Figure 6. Basic analytic framework.

Figure 7 carries the functions analysis process forward relative to a multilevel situation. This involves a grouping process that sorts BFA-derived tasks into recognized activity segments (right side) labeled as "High Level Network Capabilities Requirements." Specificity is added to each high level capability when an IR is converted to a query (see Table 4).

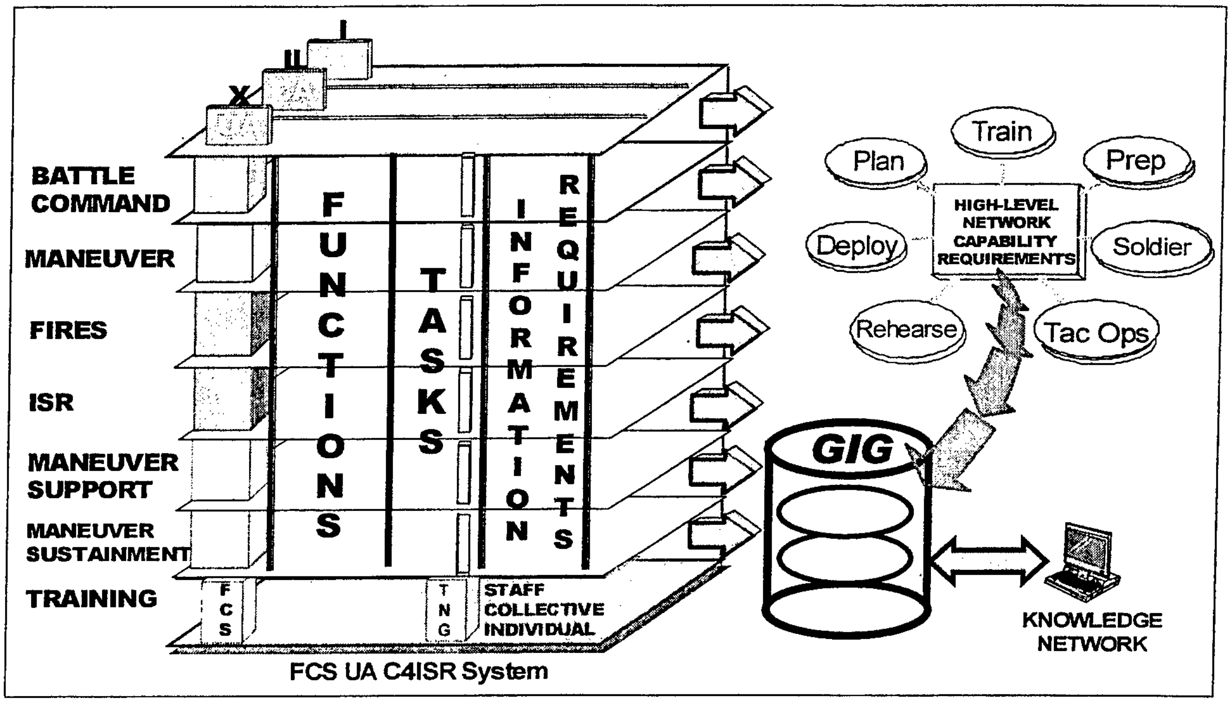

Figure 7. Capabilities mapping.

Contextual application is significant relative to where tasks and the consequential IRs fit into the activity phases of an organization's operations. The majority of staff functions and tasks could be sorted into six activity phases (DA, 2001a): (a) Train (in garrison, Combat Training Center [CTC], on-the-move and in-theater), (b) plan, (c) prepare, (d) deploy, (e) rehearse, and (f) conduct tactical operations. A seventh activity category, "Soldier," was added to cover broader IRs that did not fit into any activity phase. The "Soldier" category is similar to "Train," in that it is not necessarily associated with activities bounded by time. The fact that training, for both units and individuals, overlaps with the other five activities makes "train" a special case (TRADOC, 2003b).

The six activity phases plus the special Soldier category were used to express the general capabilities required for any useful knowledge network for the UA. Each can be parsed into enabling or supporting capabilities. A partial mapping of general to specific capabilities is illustrated in Table 4. Included in this mapping is the inference of cross-communication and collaboration which will be greatly facilitated in the network-centric UA environment (TRADOC, 2002).

Table 4

Capabilities Mapping—Partial Enumeration

Major Activity	Information Requirement Categories
Plan	Orders and plans from applicable units
	Map databases
	Logistics at staging area
	Intelligence summary on enemy or dissidents
	In-country infrastructure
Prepare	Classes of supply to be deployed with troops
	Personnel operational readiness and stop loss
	Regional geopolitical profiles
	Special clothing issue requirements
	Coalition force data
Deploy	Airlift schedules
	Locations of aerial ports of debarkation (APOD) and sea ports of debarkation (SPOD)
	Immunizations required
	Media and Public Affairs (PA) releases
	Reception, Staging, Onward movement, and Integration plans
Rehearse	Embedded maps and graphics
	Air corridors and location of suppression of enemy air defense
	Graphics and 3-D visualizations
	Urban mock-ups
	Key decision points
Tactical Operations	Unit updates
	Shared data from ongoing contacts
	Barriers executed in sector
	Resources profiles
	Follow-on plans
Train	Crew drill and virtual gunnery TSPs
	Staff training
	Lessons learned from past operations
	Crowd control and enemy prisoner of war operations
	Rules of engagement
Soldier	Promotion forecast
	Dependent dental and medical support
	Mailing address when deployed
	Health and welfare facilities
	Language training

Prototype Development

Software development began prior to conclusion of the front-end analysis phase. The results of the information engineering effort were made available to the prototype software engineers as they became available. Several key design concepts evolved based upon the results

of information engineering. It was clear that the following realities of UA operations and training must be accounted for in constructing a prototype knowledge network:

- *Compatibility.* The prototype must be compatible with the Future Force C4ISR architecture to include access to a larger GIG (Department of Defense (DoD), 2002, 2003).
- *Secure and Specialized Sources.* Information requirements for a tactical maneuver unit will focus on operations and training. Information searches through knowledge networks for these two areas must be structured and should come from predictable or prescribed sources through dedicated search channels.
- *Training Support System.* Training for FCS will be fully embedded and top-down supported, to include digital terrain databases (DA, 2002a).
- *HSOC.* A designated HSOC will provide "reach" and support to deployed units, including facilitating communication from units to a full range of information resources in the Continental United States ([CONUS] DA, 2002b).
- *Functional Indexing.* Individuals in certain functional positions within a unit will develop patterns for network use. For example, a Brigade intelligence functionary will develop a consistent pattern for searching operations sources, intelligence agencies and regional data sources.
- *Community Sites.* Community sites will provide information on regions, countries, lessons learned, studies, historical profiles, and archived data. Some existing sites are within the Army's purview while others are Joint Service, DoD or Federal Government, e.g., Central Intelligence Agency, Department of State (DA, 2001b).
- *Open Web Sites.* The broad range of information on the Worldwide Web must also be available to Soldiers searching through knowledge networks.

The range of factors obtained through our research is graphically portrayed as a set of bands that characterize the knowledge network, first through the HSOC and then to wider-ranging sites and search channels. A narrow band controlled by the HSOC facilitates a focused search of a limited set of information that is highly relevant to current operations. Wider bands include additional information that covers a greater variety of topics from operational and collateral sources. The most general band provides access to the widest range of information from government, public, and private sources found on the GIG. Figure 8 portrays the three basic avenues of operational, training, and general information searches. To illustrate the concept of banding, a query traveling horizontally through the bands will be targeted initially at or through the close proximity sources or more dedicated sources. For example, the close range Operational band should successfully complete a query searching for the current JTF OPORD. A Civil Military Operations (CMO) planner might be required to do a more extensive search that goes from country specific information contained in the UE Division Intelligence Annex (Operational band) to specifics on the political military climate (General band).

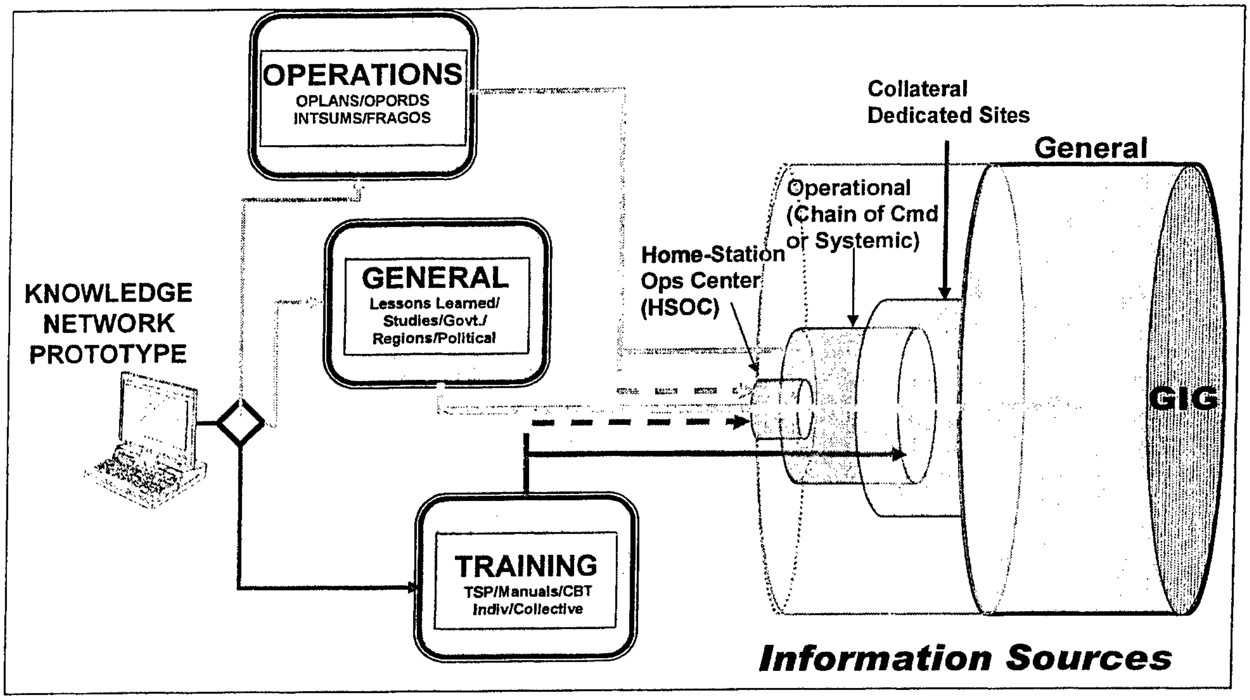

Figure 8. Knowledge network banding effect.

The technical aspects of building a prototype network were guided by the information engineering findings. We developed user interfaces with consideration for the factors discussed above. We refined the prototype incrementally by applying domain-specific capabilities highlighted by the research findings. The three search channels and the banding concept were integrated into the prototype. Use of the prototype required that a robust set of data and information files be created as credible search targets. We developed a set that was tailored to the scenario used for testing. The information package consisted of OPORD and plans (from brigade through Joint Chiefs of Staff [JCS]), intelligence summaries (INTSUM), reports, lessons-learned reports, United Nations resolutions, country studies, rules of engagement, and data on weather, urban areas, population, infrastructure, and transportation.

Prototype Description

Knowledge Network System Overview

The prototype KN provides several different methods to search for and distribute information. The goal of the prototype was to provide seamless searching for information from different types of sources. These sources included Web-based documents, databases, news feeds, personal messages (e-mail), and files stored within various repositories. If the knowledge network is capable of searching these different areas in parallel, a user should be unaware of which search bands are being probed. Rather, the user should know only what results are returned. Different methods may be preferred under different circumstances. The prototype also allows a user to put information back into the network, thereby enabling the overall structure to grow over time. Once information has been incorporated into the structure it can be searched and viewed by others.

Main Page

The prototype KN is a user-based system requiring a username and password to log on. Once a user logs on to the network, he arrives at a main page containing several different types of information (see Figure 9). The user may customize this information by selecting and/or hiding what categories should be displayed. The three main categories of information available are RSS feeds, blog messages, and quick links.

1. The RSS feeds include information from news organizations or from local or higher-level units. The user chooses which local and/or foreign news feeds to subscribe to in order to gain a better understanding of the events taking place in a particular region or category. Unit feeds provide information from and about individuals within the unit, such as meeting times, distribution of manuals, or other unit-specific details.

2. The blog allows users to post information that can be commented on by other users. The user can easily use a blog to obtain information on a particular topic by requesting for a comment on the topic of interest. An individual may have a question pertaining to a subject for which the answer may not be found on the Web or in other documents available to the user. The blog forum allows a user to post a question without the need to call around trying to track down someone who may have the answer. Blog messages also are a valuable method of distributing information within and among groups.

3. Quick links allow a user to publish a listing of his most frequented sites. Placing these links on the main page permits a user direct access to a predetermined set of frequently used resources. Note that these links, as well as the feeds, are customizable to the particular user. Each user has the ability to control what information gets shown on his individual main page.

Searching

Searching is one of the primary components of knowledge networks. The prototype includes several methods for executing a search. Simple text-based searches are not necessarily the most straightforward method in all cases. Users unfamiliar with a topic may not know what keywords to enter (e.g., when looking for information on a particular region in a foreign country). Alternatively, users may know exactly what they are looking for and where it might be located, but they may need a means of finding it. The prototype network provides three methods of searching and locating information:

- Full-text searching.
- Concept-based searching.
- Fixed-document (menu-driven) searching.

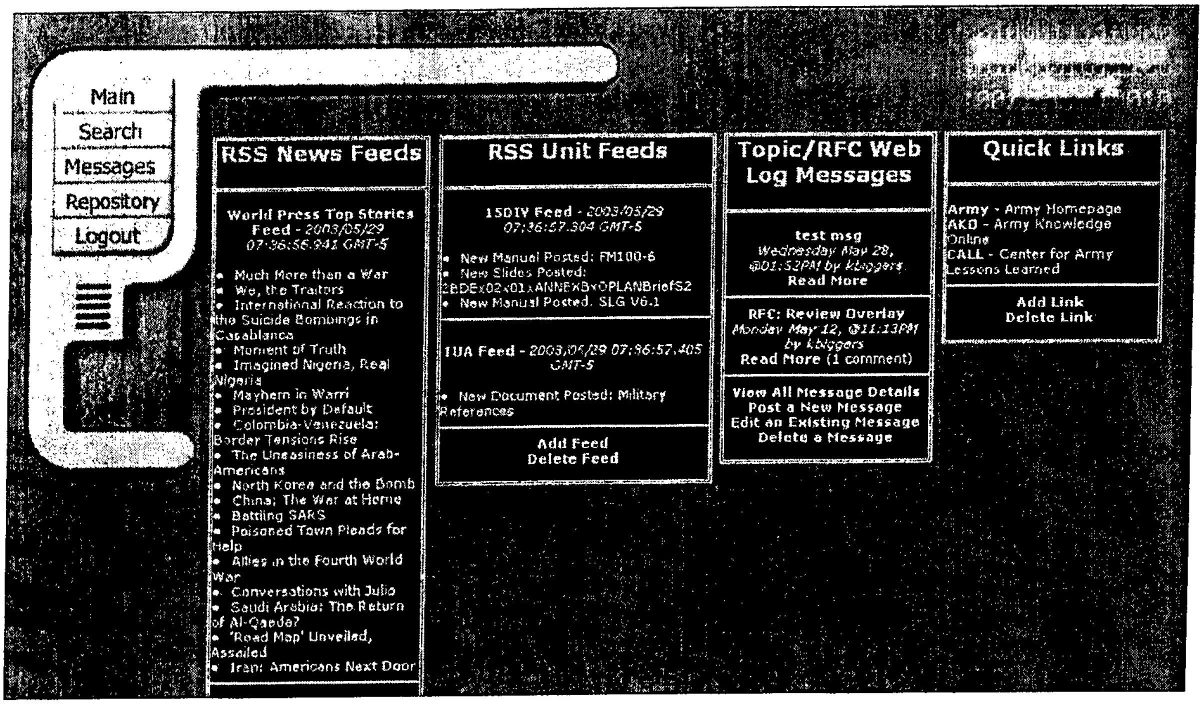

Figure 9. Knowledge network - main page.

Each of these methods provides a user with a different means of obtaining information from the system. The type of information the user is searching for and how familiar he is with the subject influence what type of search he might use. Different users may also have a preference for a particular means of searching. For example, some users may prefer full-text searching capabilities that mimic those of Google™ and other familiar Web-based tools. Others may be less familiar with these tools and may prefer a more visual approach that allows them to drill down through a set of concepts they understand and can visualize. Once they reach a level in which the information they are after could be located, they can then execute a search and the documents related to that particular concept or set of concepts would be returned. Users who know exactly what they are looking for and basically where to find it may prefer a fixed-document search in which they can select the specific details from a predefined list.

Full-text searching. Because of its familiarity to most users, we believe that full-text searching will be a frequently used search method. Within the prototype knowledge network these are termed as general searches (shown in Figure 10) and simply allow a user to enter a set of keywords to search on. In addition, the user has the ability to select which information bands to search. This capability gives users more control over what types of documents get returned. For example, if the general band is selected, the user will likely get overview Web pages on a topic, whereas if the HSOC band is selected the user would get detailed training and FMs related to the types of missions his unit is likely to perform.

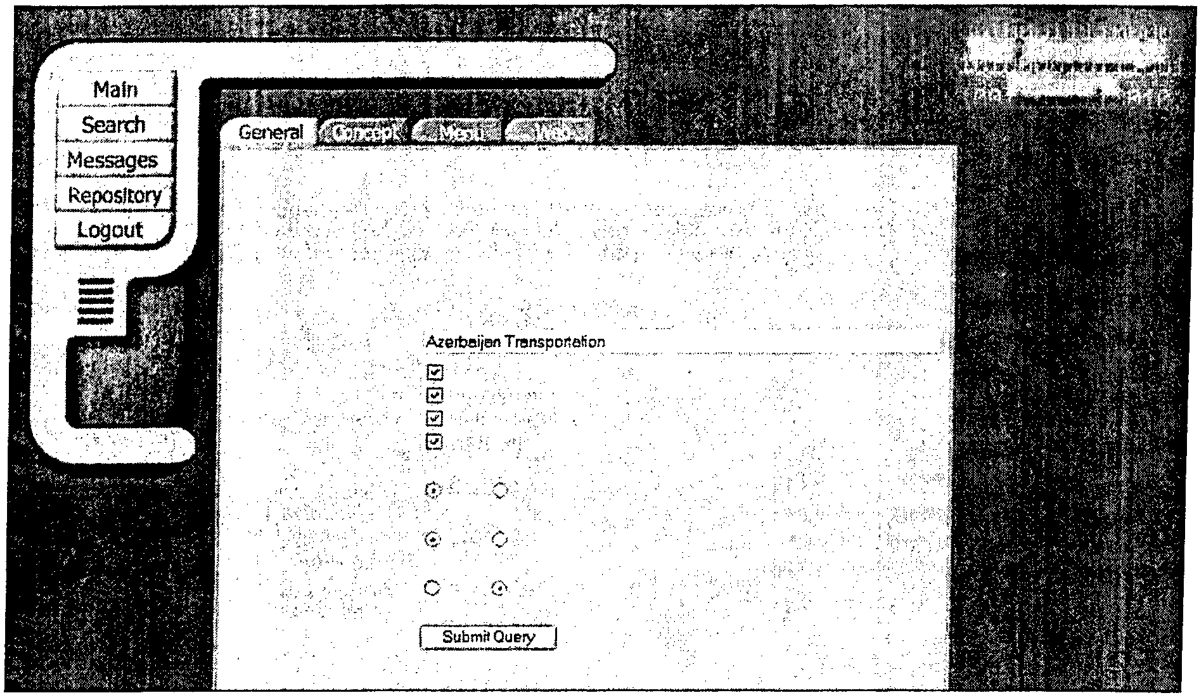

Figure 10. General search.

In general searches, users also have the ability to turn on and off various features of the system. By adjusting these features, the user can affect the priority of the documents that get returned (with higher priority documents being listed near the top of the list). When executing a search with the various features turned off, the system simply performs a Boolean-based search. All documents that match the query will get returned in the order that they are found, without ranking. There is thus no real way to evaluate the documents other than looking through each one by hand. The page-ranking feature allows for simple frequency counting within the documents to influence the ordering of how they get displayed. A document that has many more instances of the search terms will appear higher up than one that has fewer.

A second feature of general searches that the user may select is user profiling. User profiling attempts to tailor information based on a user's role or duty position. For example, an intelligence officer who executed a search of a particular country should expect to get information that is more related to terrain, enemy tactics, and so forth, whereas a CMO would get information more related to government and politics of the country. The profiling system attempts to recommend information that is more related to the user's role. Finally, users can select whether or not they want their search results to be placed back into the system and indexed. Placing search results back in the system allows future users to search another individual's search results.

Figure 11 shows the search results that were returned to a query executed on "Azerbaijan Transportation" with all optional features enabled. For each item returned, several types of information get displayed. The first item is the document name and a link to its location so the user can download and view it. The band in which the document originated is also given. This gives the user a better feel for where the information is coming from and allows him to evaluate in more detail what results may be most relevant to his needs. If user profiling is turned on, then

some additional information is also displayed. The profiler determines which category the document best fits into and then uses this to evaluate the information's interest level to the user based on that individual's role. In Figure 11, most of the results deal with transportation, as expected. The final column displays the document reliability. In the prototype, this reliability is determined based on the band in which the document appears. In an operational system this determination would be a far more complex process involving the source of the information, its age, and other factors.

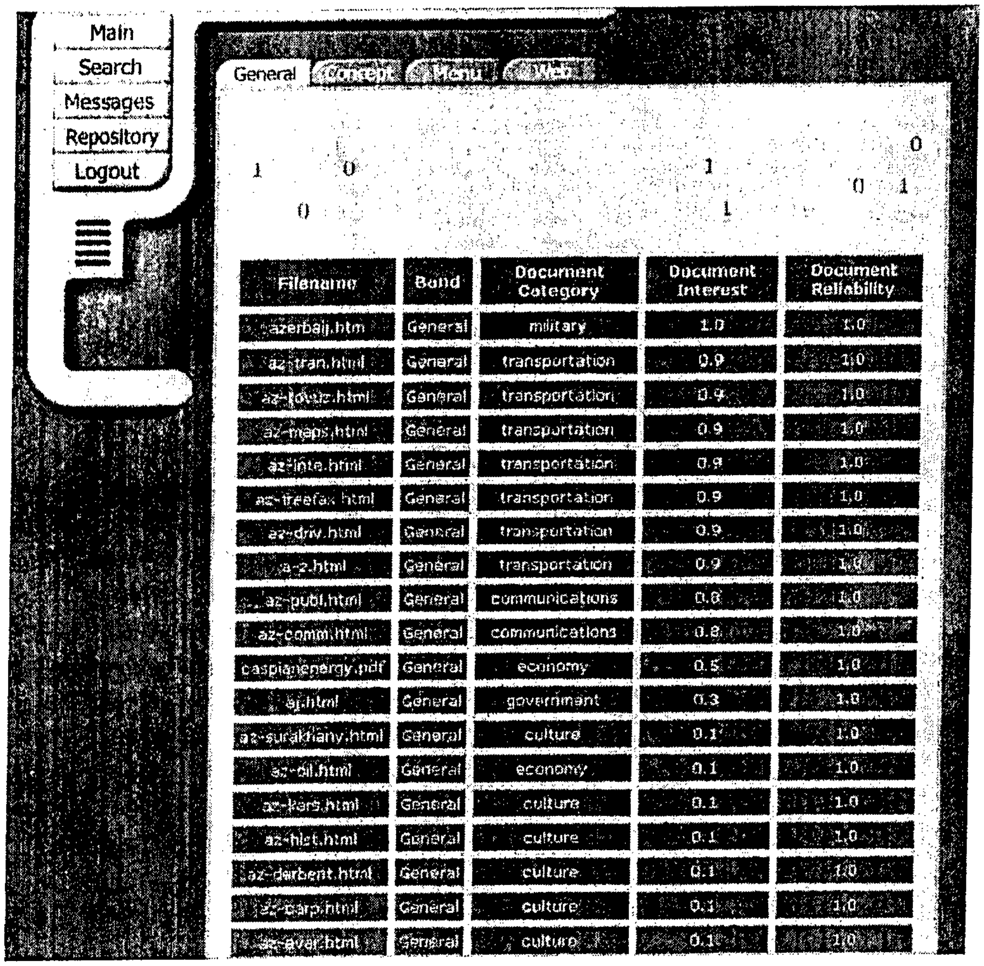

Figure 11. Search results.

Through the use of a fairly complex algorithm (such as a rule-based system), it would be possible to estimate whether a given piece of information could be trusted or should be discarded. One possible extension to the current results displayed would be to add the ability for the user to sort based on the different columns. Currently, it sorts solely based on the document rankings. Adding the column-sort would allow a user to evaluate the information based on different perspectives.

Concept-based searching. Concept-based searches allow for a more visual execution by allowing a user to drill down through a set of concepts. Although the prototype does not include

a working version of concept-based searching, it simulates how such a capability would work from the user's viewpoint. Figure 12 shows a small representative sample of a concept map. In an actual search, this structure would be automatically generated through the use of clustering or some other data-mining technique. The user would first enter a starting term, for example "Azerbaijan" as in the example, and the system would generate and display the information in this type of format. The user could then click down through the structure. If the structure is large enough, the display may need to be multi-dimensional. A similar application is the engine developed by Semio used for the Center for Army Lessons Learned ([CALL] U.S. Army CALL, 2003).

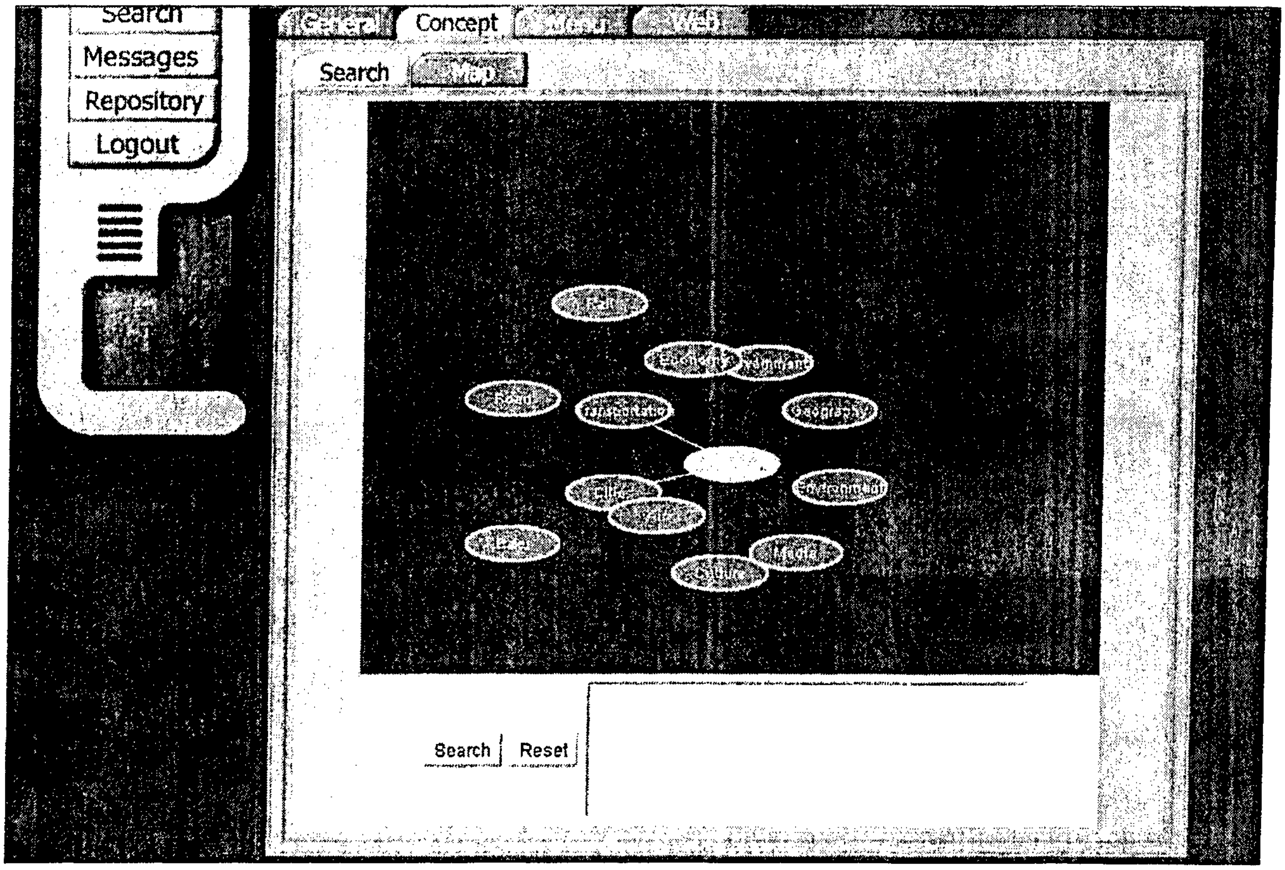

Figure 12. Concept search.

Two categories of concept searches were simulated in the prototype—a typical concept search and a search based on concept maps. Each of these works in a slightly different fashion. In the concept search, as a user is making a path down through the structure, the search engine tracks what items the user selects. When the user finally executes the search by pressing the button, the engine looks at the index and returns all documents that match the complete set of search terms the user selected. The concept map works slightly differently. The map never looks at the index when a search is executed. Rather, for each node in the graph there is a set of links to documents attached. For example, if a user were to select the geography node and then select search, a set of links involving maps and reports on the selected countries' geography would be displayed. These documents would be linked beforehand, obviating the need to search the index. Documents can be linked in one of two ways:

1. Users can link documents to nodes as they come across them.
2. Users may use data-mining/machine-learning algorithms to automatically generate the structure and link items to their proper nodes.

Menu-based searching. The third category is a menu-based search (shown in Figure 13). A menu search allows a user to locate a particular document that he knows exists. For example, if a user were seeking a document on virtual training environment related to urban terrain and knew the document had been posted, a menu search would enable him to locate and access it simply. The user would select the training tab, followed by the collective training tab, and then select the unit type and desired echelon. The search engine would present all documents matching the search, permitting the user to page through and find the desired document. Similarly, a user could look up information with respect to operations or regional data. Several additional subcategories are listed below each element.

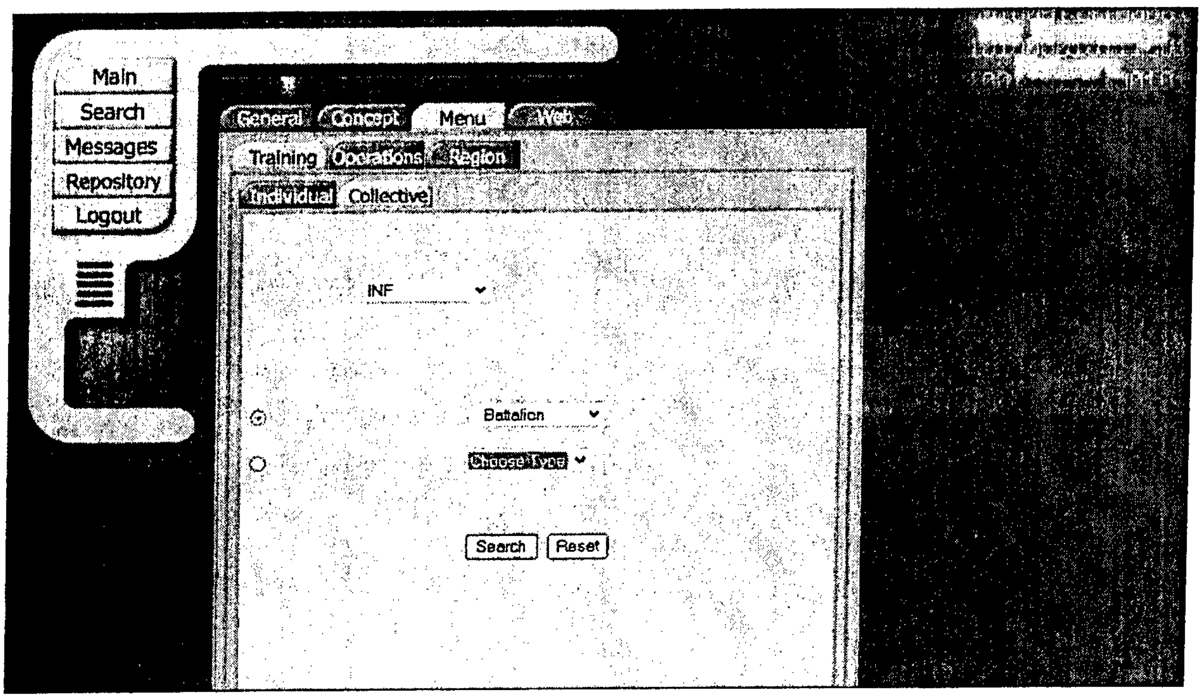

Figure 13. Menu search.

Generic Web-based searching. In some cases user may be looking for general information located only on the Internet (an unconstrained search in the last band). To access this information, the prototype provides users with the ability to conduce Web-based searches (Figure 14) directly, using some of the most popular commercial search engines available on the Web. The user enters the search terms in the specified box, selects the engine he wishes to use, and hits the search button; he will be automatically transported to the engine and the search will get executed.

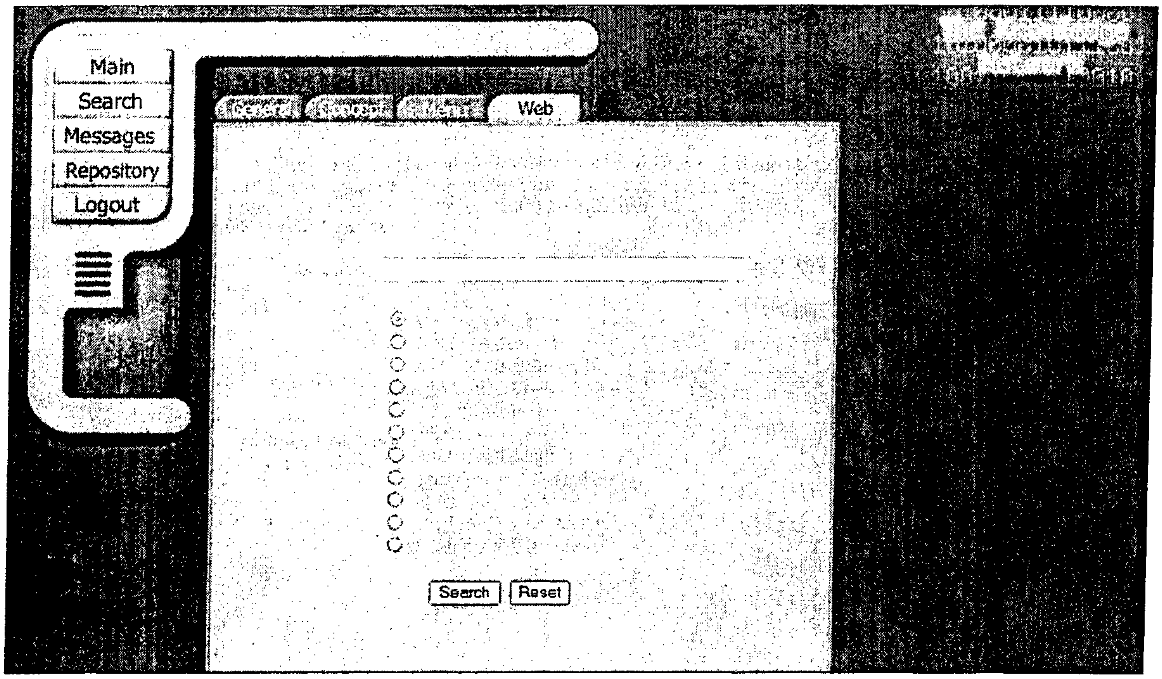

Figure 14. Generic Web search.

Adding Information to the Network

Aside from searching, the user can also put information back into the system through one of several different methods. These include:

- Subscribing to different news/unit feeds.
- Posting or replying to blog messages.
- Sending or replying to personal messages.
- Posting documents into the local or unit's repository.

Information put back into the system can be incorporated into the index (once the index has been rebuilt) and is fully searchable by all users. Every time a user updates his news/unit feeds, posts a message to a blog, sends a personal message, or loads a document into the repository, the information is copied into the cache of documents that are used to build the index. Attached to each document is also metadata that stores where the object came from and its band. As more information gets loaded into the system over time, it will become more comprehensive. The ability to put information back into the system to enlarge and improve the available data is very important to the concept of knowledge networks. Through information sharing and growing the overall structure, the network is made more usable and more powerful.

Implementation Details

The overall prototype knowledge network uses the Zope Content Management Framework ([CMF] Zope Corp., 2003). Zope is a framework for building custom Web-based applications. Zope is supported by a large community of developers who have created (and

maintain) many different modules. Because these modules are available, a site can be more quickly developed by facilitating code reuse. Zope is built in the Python programming language and supports scripting, HTML, and dynamic template markup language ([DTML], a Zope-specific language for generating more dynamic pages) development within its framework. The prototype knowledge network uses a combination of Python scripts, HTML, DTML, and both Java and C code.

The prototype framework is divided into several modules (shown as boxes in Figure 15). The components include:

- Crawler.
- Searches.
- Index.
- Blog.
- RSS Feeds.
- Personal Messages.
- Repository.
- System File Import/Export.
- User Profiler.

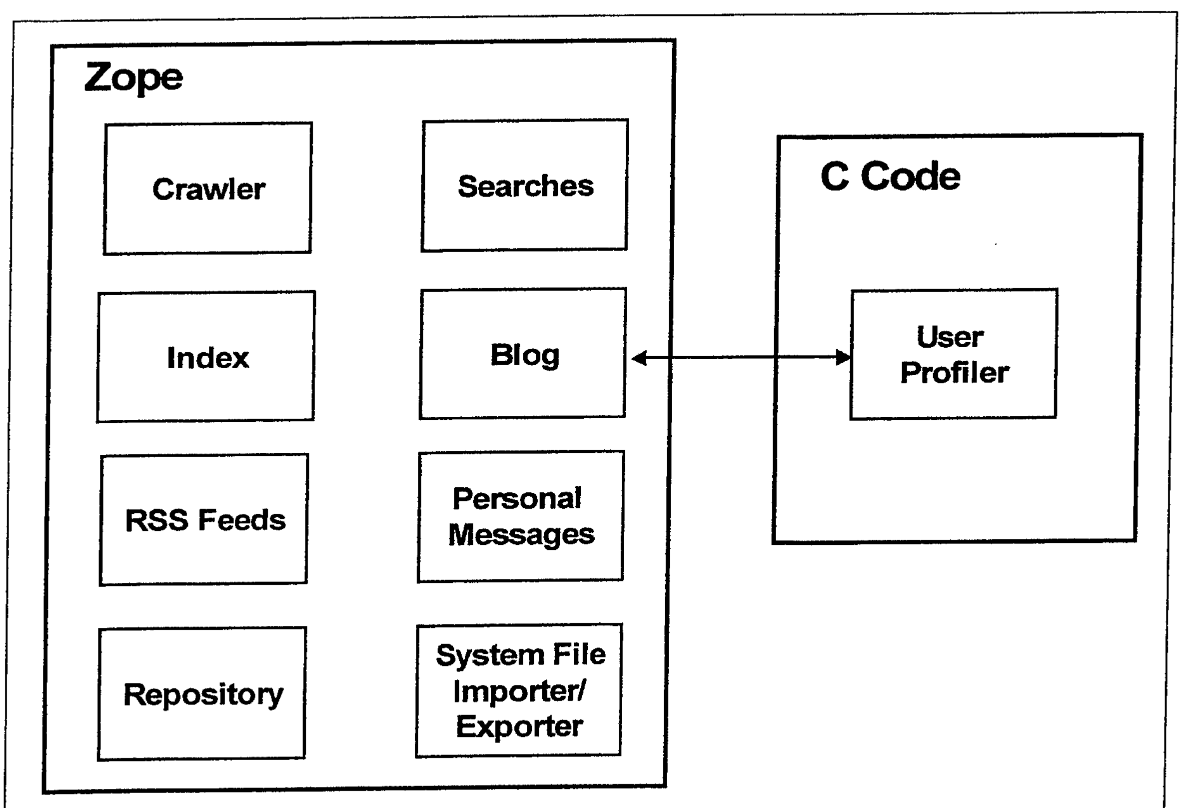

Figure 15. Knowledge network framework.

Crawler. A crawler works in a fairly simple manner. Within the prototype knowledge network, a page under the crawler folder allows a user to submit a URL for crawling. Once the user presses the submit button, the crawler begins to retrieve documents for indexing. The user can specify how many levels the crawler will go before stopping. We recommend that users strictly limit the number of search levels, because the greater the number of levels, the more information is brought into the pipeline. The Web hierarchy is a tree-like structure and the volume of information increases greatly with each level added.

This fairly simple method used for the prototype could easily be extended to store URLs in a database and direct the crawler to periodically browse the URLs for new updates at the various sources. The crawler is based on the common UNIX utility *wget* (GNU Project, 2002). *Wget* is a freely available software package that allows for retrieving files using one of several protocols. *Wget* has multiple features that allow for transferring large files as well as mirroring sites.

Blog (Weblog). The blog is based on the very popular Zope product, Squishdot (Landingin & Withers, 2003). Squishdot is freely available open-source software that allows for the publishing and discussion of information through the use of a Weblog structure. The generic Squishdot framework is integrated into the prototype system. The prototype allows the user to view and post messages as well as to comment on previously posted messages. Document attachments are also allowed, so a user could attach a manual or digital overlay for others to evaluate and provide feedback. All information posted to the blog will also be included into the index and will be searchable once the index has been regenerated.

Rich Site Summary (RSS) Feeds. This section of the prototype network is built from the Zope Resource Description Framework (RDF) Summary module (Zope Corp., 2003). This module allows a user to specify the URL where a particular feed is distributed and upon request will connect to the site and capture the feed, process it and store the information so it can be displayed and used as needed. This module is integrated into the knowledge network and each role has a set of associated feeds. In actual use, it would be best for each user to be able to control what feeds would be displayed on the main page. This degree of customization would be possible by providing a master list of all available feeds accessible by the network to its subscribers. The feeds can be updated in one of two ways: a button appears on the page that allows the user to select when the feeds get updated (how the prototype functions) or a timer could be used to determine when the feeds are to be automatically updated. A combination of the two, providing for automatic updating, but permitting the user control over when to receive the updates would be the best solution. The time the feed was last updated gets displayed along with the information so the user can easily determine its currency.

Index. The index is also built from a series of Zope modules. For information on searching and cataloging content within Zope see *The Zope Book,* (2003). All documents incorporated into the index are stemmed and the stop words are removed. The indexes are compressed in order to reduce storage space and speed up the searching process. The index for the prototype system is broken into two separate indexes that can be searched in parallel. The first index contains all of the documents collected by the crawler. The second index contains all

the remaining documents collected from sources such as repositories, personal messages, feeds, and blogs.

Separating the indexes has several benefits. First, the indexes can then be regenerated independently. This allows an index that requires frequent updating to be regenerated without the time burden associated with regenerating the entire large index based on documents collected by the crawler. Secondly, it allows for more control when performing a search. If a user is not interested in the information gathered by the crawler, he can limit his search to the index that contains information from sources other than the crawler. The indexes could be split into more than just the two demonstrated in the prototype, providing users with even more control over where they choose to search and thereby speeding up the overall process by reducing the number of matching documents returned after executing a search.

Search Methods. The search methods used in the prototype consist of a combination of Python scripts and Java code. Zope provides several methods for accessing the indexes. We extended these methods greatly in order to achieve the desired level of functionality. Additionally, we attached metadata to all documents to enable the system to search based on the bands and to estimate a document's reliability. When a user selects the bands in which he is interested, the metadata are analyzed and only information from those bands matching the search parameters will get returned.

The general search uses a set of methods written in Python. If user profiling is turned on, the resulting document list from a search is passed to the profiler. The profiler returns a set of newly ordered documents based on an estimate of the interest levels of the user.

The concept searches are implemented as a Java applet (a small program that can be embedded in an HTML page). The applet tracks the items a user selects and makes a call to the appropriate general search function, with the user selection passed as a parameter of the call.

The fixed-document searches use DTML and Python scripts. Each menu item is mapped to a folder in which the relevant documents are placed. When a user executes a search, all documents stored in a particular folder get returned to the user.

Finally, the Web-based search simply takes a set of search terms from the user, formats a search string for the particular search engine of choice, and calls the engine with the search string. The user is then transferred to the results page for that engine. The search module is by far the most complicated in the prototype and integrates several different components to achieve functionality.

Personal Messages. Personal messages within the prototype use a simple Internet Message Access Protocol (IMAP) client for mail storage and retrieval with one extension. The messages that are sent get incorporated into the overall structure of information made available to the user. Much of the information communicated between individuals may be potentially useful to the user community at large. This information is made available by incorporation into the index. These messages are not intended to be used as normal communication between individuals, but rather as a source for questions and answers and the communication of important

information within the framework. If such a method were to be used outside of the prototype, users would likely demand more control over whether their mail were placed into the index.

System File Import/Export. This tool was implemented in Python to allow documents to be brought into the prototype network easily. This module can be found under the Menu/Import folder. A user selects the document to import, identifies the location to place it, and selects the band with which the document should be associated. This interface is not intended for general users but is focused towards the administrators running the system to allow them to bring documents into the system quickly.

User Profiler. The user profiler attempts to place documents into their best-suited category. Currently, the following nine categories are used: Communications, culture, economy, environment, government, health, military, security, and transportation. This list could easily be extended to include many additional items. In general, the set of categories should be tailored to support the appropriate application domain.

The user profiler integrates several different technologies to assist users in finding interesting and relevant information more quickly. Each user has an associated role and each role has a customizable set of categories associated with it. By evaluating to what degree a document fits into these categories, a document can be assessed a predicted interest level for a particular user. This assessment is broken into five interest levels: very interesting, interesting, neutral, not interesting, and not interesting at all. A user's profile (based on his role) is updated every time a query is executed, so that, over time, it will better learn what type of information he prefers. The prototype system filters this information through the use of a series of algorithms. These include: (a) a category trainer, which trains each category to identify documents that fit into it by evaluating a set of collected data specific to that category; (b) the document classifier, which fits a document into one of several different categories; and (c) the user's interest evaluator, which, for a given document and associated category, determines a user's interest levels for a particular document. The profiler uses *k*-means clustering to classify user interests and a simple Euclidean distance to measure the similarity of a matched document to a particular user's interests. *K*-means clustering is ideally suited for this application in that it generates a specific number of disjoint, flat (non-hierarchical) clusters and produces a numerical solution in an unsupervised environment.

These modules (as shown in Figure 15) are integrated into a common framework that forms the prototype system. The framework has been extended by adding features such as the ability to store previously executed searches. The overall system, developed solely as a prototype, has limitations regarding the local data available to it, the reliance on freely available tools that do not offer the capabilities of commercial tools, and the incomplete implementation of some capabilities, such as concept searching. However, at the current level of development the prototype provides a test environment for exploring technologies related to information retrieval, indexing, searching, and user profiling and for determining how they may be used to support IRs for the Future Force.

Knowledge Network System Innovations

The prototype knowledge network incorporates several innovations resulting from the integration of different technologies within a single framework. The prototype provides the user more control over the information obtained from the system, compared to existing search engines and related tools, as well as the ability to easily distribute and make new information available to other users on the network. Information acquisition and distribution are thus integrated into a single, consolidated framework. The prototype also allows a more dynamic exchange of information within the system—an exchange that goes beyond that which standard search engines provide today.

The control provided to the user by the KN over how to search information can be viewed as the primary benefit of this tool. By allowing users to select from different search methods depending on the subject and their knowledge of what they are looking for, the system allows them to locate the desired information more easily. Additionally, by allowing control over where information comes from within the bands, users can reduce the overall number of documents they have to review to obtain the sought after information.

A second benefit of the prototype is that it allows for a more productive and usable system by integrating methods to share information with other users of the network. This capability can expand the impact that information has, by allowing it to be shared among the members of the UA, or between the UA and other units.

The third notable benefit is the concept of seamless information searching. Within this network, users could simultaneously search information stored within different indexes and databases, whether on the Web or in local repositories. By allowing users more control over the source of the information they retrieve, the system becomes a more useful and valuable tool. This combination of being able to control where the information is coming from and to use different means of searching for the same data makes the prototype a more flexible system.

Knowledge Network Prototype Demonstration

A demonstration of the prototype knowledge network was conducted at Fort Knox to generate feedback and provide the basis for adjustments in design and capabilities prior to project completion.

Participants

Army Research Institute (ARI) personnel at Fort Knox arranged for four Soldiers from the Unit of Action Maneuver Battle Lab (UAMBL) to participate in the demonstration. Two were commissioned officers and two were NCOs. A separate demonstration was conducted for each participant.

The participants differed in their knowledge of Future Force concepts and of battlefield automation systems. Both of the officers were assigned to the UAMBL, and consequently were relatively familiar with the capabilities and other characteristics of the Future Force, as well as

the relevant requirements documentation. In addition, one had a background in information technology, while the other had experience as an intelligence officer.

The NCOs had considerable (15–20 years) Army experience, but little knowledge of Future Force requirements. In addition, one had little experience with digital versions of weapon systems, such as the M1A2 or the System Enhancement Program versions.

Method

Demonstration scenario. A specific mission thread was selected as the foundation for the scenario used to demonstrate the prototype network. The selected thread was "UA Brigade conducts operational maneuver over strategic distances to an austere theater into multiple locations" (USAARMC, 2002a). With this thread as the anchor point for analysis and scenario and vignette development, the demonstration participants were instructed to consider the actions of the UA staff and commanders that would be conducted at each of the following three times.

1. From receipt of the Alert Order through deployment from an aerial port of embarkation to arrival at an aerial port of debarkation (APOD);
2. Subsequent in-theater actions relative to reception, staging, onward movement and integration; and
3. During preparation for onward movement.

A realistic scenario for a UA operating in 2015 was developed to provide information for prototype development and demonstration. The vignette was based on Vignette 1 (Annex F) of the O&O Plan (TRADOC, 2003b). In the vignette, a UA is alerted and then ordered to deploy as part of a UE Division to the country of Azerbaijan to conduct stability and peacekeeping operations in an unspecified sector.

Procedure. The demonstration allowed each of the four participants to role-play as an ISR officer, a CMO officer, or as an NCO in these functional areas. These areas present two different perspectives on the types of IRs that would be required to complete the mission. On a concept basis, the more open and unrestricted of these areas is CMO because the IRs deal with a broad range of topics from regional terrain to civilian authorities and infrastructure. Intelligence addresses a balance of closed net classified data retrieval, as well as open terrain and climatic data. We believed that the two roles considered in the demonstration provided an environment in which we could adequately demonstrate all features of the prototype.

At the beginning of the demonstration, the participants reviewed written material that described the scenario and summarized the road to war. The description included a description of the relevant geographical, political, and military events that had occurred before the beginning of the scenario. It then summarized the mission and provided orders and other related material. After the participant read the material, we answered any questions that he had about the mission.

The participants then received an overview of the design goals and capabilities of the prototype KN and a quick tour of system functions. The overview described the general

capabilities of the system, illustrated how the system was controlled, and gave some examples of specific functions, such as searches or RSS news feeds.

Participants then began the hands-on role-playing exercise using the system to identify specific information required for either Intelligence or CMO. In general, we prompted the user with an IR, which he then tried to satisfy using the prototype KN. We gave the participant as little help as possible, but did provide assistance in operating the system when it was needed. Also, we sometimes suggested that the participant use specific capabilities, to help ensure that all of the functions were covered. For example, we encouraged the participant to use all types of searches. The demonstration continued until all of the features of the prototype were covered and the participant had no further comments. Time for the demonstration varied between one and two hours.

The demonstration was conducted on a laptop with a wireless connection to the Web server. Observers watched a second display that was connected to the laptop and took notes of participant comments.

Results

The primary results consist of the comments of the four participants in the demonstration. Although it is difficult to generalize from such a small sample, the reactions of the participants did provide useful information, which provided the basis for several enhancements to the prototype software. We organize the results from these comments by prototype function.

Searching. The participants tried all three search methods (text, concept, and menu search). Their preferences differed, especially with regard to concept searches. One of the officers preferred the text search to the concept search, in part because it supported a general search strategy that allowed him to review a list of matches to identify the relevant material. However, the second officer preferred the concept search, because he was not happy with previous experience with text-searching capabilities of commercial search engines such as Google™. One of the NCOs was favorably impressed with concept searching, as well.

The participants saw different uses for the different search methods. For example, one officer used the menu search capability for finding formal documents, such as training manuals or other official publications. The organization of the menus allowed him to locate the desired information quickly. A text or concept search, on the other hand, would be more appropriate for more open-ended searches.

Participants saw benefits to the banding concept in identifying the most relevant search results. One of the NCOs indicated that it was already difficult to find documents, such as forms, on Army Knowledge Online (AKO), because of the wealth of information accessible from that site. The other NCO stated that the HSOC would be the primary source of information for the vast majority of IRs, implying that banding would be a very effective strategy.

Sharing information. One of the officers stated that blogs could provide useful information to a unit that is preparing to deploy, including environmental conditions, special

requirements, need for special equipment, and other information. An NCO echoed this opinion and added that blogs could provide information on enemy capabilities, weapon types, and other enemy characteristics. In a related topic, one of the officers suggested that it should be possible to forward the results of a search to others who may also need that information.

Display features. Participants had a variety of suggestions for new display and control features. These suggestions are enumerated in the following list.

- Use more hot buttons rather than fill-in menus to initiate common searches;
- Add audio and visual alerts for time-critical information;
- Provide additional main-page information including some form of "ticker tape" for information such as weather information or alerts;
- Use key words or buttons to access training documents such as TSPs; and
- Make key information extracts available in bulletin board format (e.g., rules of engagement, hazardous conditions).

Integration. Participants expressed concern that the knowledge network provide a consistent interface in different situations, and that it should be consistent with other systems, from the user's perspective. One officer stressed that the same interface should be useable both in garrison and on deployment. An NCO expressed the opinion that the display should be consistent with other vehicle displays to the extent feasible. Finally, they suggested that it would be useful to make the information portable by integrating the network with personal digital assistants (PDAs).

Other comments. One of the participants suggested that different information should be available at different echelons. For example, news feeds would be most useful at higher levels (e.g., for the UA staff). In addition, participants made several specific suggestions about terminology, output details, and specific options included in the prototype.

During the demonstration, the participants mentioned several times that users would want control over access to information. This level of control goes beyond simple password protection of pages. The desired capability would allow users to define groups and to specify which groups have access to a particular piece of information, thus allowing users more control over the distribution of information. Limiting access would enhance security, reduce the likelihood of information misuse, and protect against inappropriate use of draft documents.

Interpretation of Results

The results of the demonstration should be interpreted in light of the preliminary nature of the prototype. Specifically, the prototype was developed over a short time, and thus many of the features (e.g., concept searching) were incomplete. Additional limitations of the demonstration result from the fact that it was conducted 12 years in advance of the period that it was emulating. Therefore, the range of the search activities was limited for the training and operations channels.

Further development of the system would complete the representation of existing capabilities and provide additional features. These features would provide better control over the information that gets displayed (e.g.. controlling what feeds, links, and blogs can be displayed on the homepage) and might be tailored to the user's role.

Nevertheless, the reaction of the participants was generally positive, and they clearly perceived the usefulness of most of the features of the prototype. Their suggestions provided guidance for refining the system features and incorporating new capabilities.

Discussion

The Future Force will operate in an information-rich environment in which understanding the implications of available information and using this understanding to construct appropriate action plans will be required for victory. Soldiers and units in the Future Force will benefit from methods to retrieve and organize information efficiently and to share it with others who may need it. The research described in this report developed a prototype network integrating several information storage and retrieval methods that could be used to support Soldiers and units in the Future Force. The prototype was developed using freely available tools, and a combination of developed and open source components. We demonstrated the prototype to several Army officers and NCOs, who provided their opinions and impressions of both the functional nature of the tool and its usefulness within their current activities. The overall user feedback was positive and provided guidance for system revisions and enhancements.

The prototype was based on reviews and analyses of Future Force IRs and technologies used for information search, retrieval, storage, and sharing. The review of IRs identified the types of information that would be needed to support the operations and training of Future Force units. The results of this analysis were used to define the required capabilities of the knowledge network. In a similar fashion, the analysis of technology focused on existing technology that had the potential to meet some or all of the needs of the Future Force. Although the capabilities that were incorporated into the prototype KN already existed in some form, they continue to be enhanced to improve their performance. Consequently, future systems that take advantage of enhanced capabilities of the technologies should provide additional benefits to users.

The prototype network integrated a variety of methods to search and retrieve information, to receive updates about ongoing information needs, and to share information with others. The methods were designed to provide the Soldier with needed knowledge quickly and efficiently, and to minimize the amount of extraneous data that would get in the way. Differences in user information needs and preferences were accommodated by providing multiple search methods and by user profiling. The ability to update repositories was provided through messaging services, web logs, and file posting utilities. Although the databases were necessarily incomplete and could not include the actual documents that would be available a decade from now, the functions were represented by working versions, rather than display mockups or storyboards.

Despite limits in the extent of the prototype demonstration, it illustrated the functions performed by knowledge networks, provided a way to obtain the impressions of potential users, and generated a list of suggestions for improved system functions. The positive response speaks both to the recognized need for the capabilities and the ability of the functions included in the

prototype to meet that need. Obviously, more definitive conclusions would require both a larger sample and a more rigorous evaluation plan.

We believe that the capabilities of the prototype and the results of the demonstration justify further efforts to develop knowledge network capabilities and to integrate these capabilities into Future Force C4ISR networks. We continue this discussion by addressing some issues related to implementation. Then we discuss the role that information engineering played in the development of the prototype and its importance in the development of operational knowledge networks. Finally, we briefly list several attractive prospects for future research and development efforts.

Integration of Knowledge Networks into Future Force C4ISR

We believe that the kinds of features that were included in the prototype will provide essential capabilities for UAs to perform their missions. The need for these capabilities is clear, and the prototype has demonstrated the feasibility of existing technology to meet the need, although further development is undoubtedly required in some areas. Further development and analyses will be required to establish the utility of knowledge network technologies. In addition, development must address several implementation issues.

Need for Capabilities

The explosion of information available to Soldiers and their units is certain to continue to affect the Future Force. The Army plans that FCS-equipped units will be networked horizontally and vertically at all levels (TRADOC, 2003b). In this environment, fast, smart and efficient searching techniques that can be engineered to meet the training and operational needs of a unit will be vital to the UA to ensure that it meets goals for adaptability and flexibility.

Feasibility and Acceptability of Technology

The prototype knowledge network demonstrates the feasibility of many of the technologies to support operations and training in a limited information environment. It should be pointed out that the freely available tools that were used for the prototype are not as capable as commercially available tools. In addition, most of the tools, such as indexing and search algorithms and user profiling methods, are the subject of considerable ongoing research, so that future systems will be much more capable. Consequently, it seems reasonable to conclude that with the normal progress of information technology, it will be possible to meet the information needs of the Future Force.

Utility of Technology

This research did not evaluate the utility of the technologies that were incorporated into the prototype to support better or quicker decisions. Nevertheless, it seems to be an intriguing possibility worthy of further study that some of these technologies can improve decision speed or quality by enhancing the performance of certain elements of the decision-making cycle.

The decision-making cycle describes a process that begins with sensing relevant information on a situation, and continues through activities that process the information to better understand the situation in order to make a decision that is converted into action. The impact of the knowledge network on the decision-making cycle is best illustrated using the cognitive hierarchy first described in Figure 2. It seems possible that a properly designed network could provide information to Soldiers that would be more readily usable by them, in effect bypassing or shortening some of the processes required to obtain and assimilate information. The potential improvements in the decision-making cycle are illustrated in Figure 16 in the context of the cognitive hierarchy. On the right side of the figure, initial processing is compressed and the overall cycle time is reduced.

The potential improvements in the decision-making cycle are in no way guaranteed, and undoubtedly depend on many design and implementation factors, including the following:

- Comprehensive information engineering,
- Fast, smart, cognitively adjustable search engines,
- Differentiation between data and processed data sources,
- Tools that provide incentives for information sharing and collaboration, and
- Interoperability between networks and battle command system tools for problem solving and decision aids.

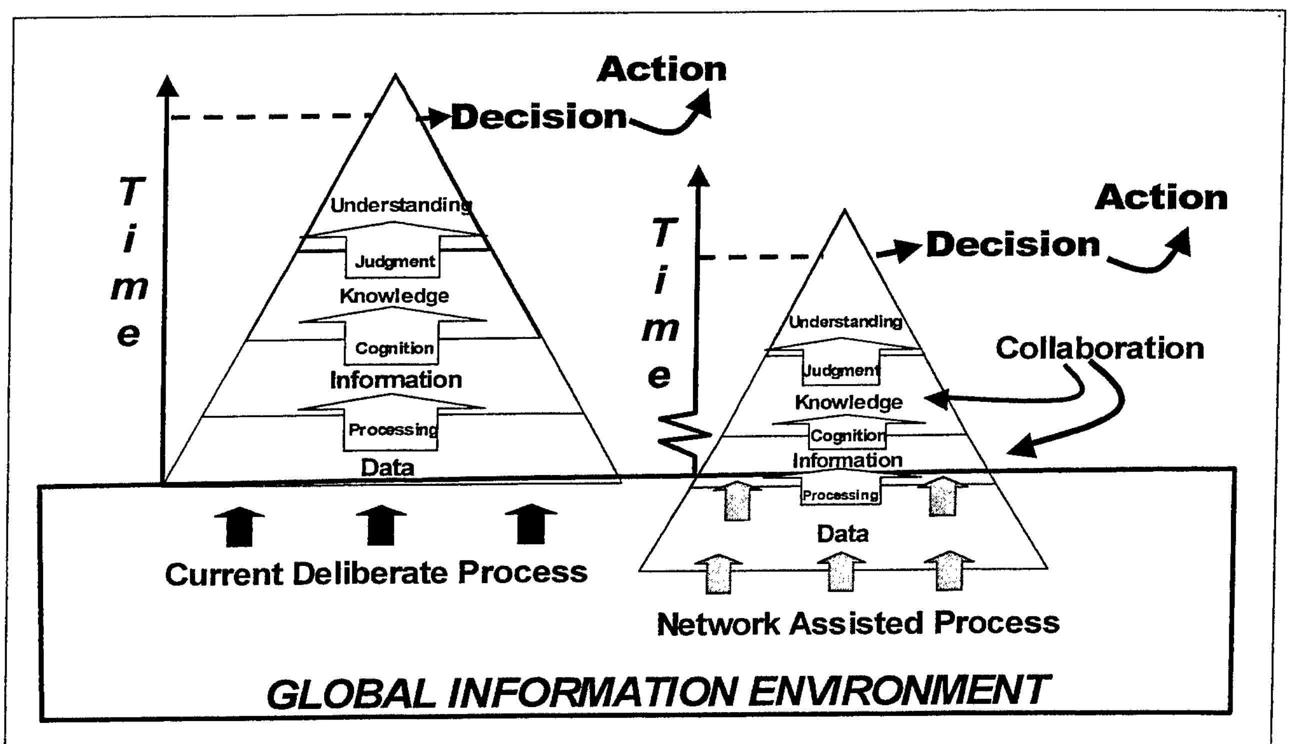

Figure 16. Potential reduction of time requirement for decision cycle.

Although these improvements have not been demonstrated, they should be incorporated as development goals and evaluation criteria for future development efforts.

Implementation Issues

Future knowledge network development should build upon the developments of other programs under construction for Future Force use. Such programs include the Army Knowledge Management (AKM) and Army Knowledge Enterprise (AKE) programs, as well as the information and methods included in the U.S. Army CALL Web site. In the training arena, the Army Training Support Center (ATSC) is sponsoring a project to develop an Army Training Information Architecture–Migrated (ATIA-M). This program is intended to provide a suite of Web-based training support applications.

Implementation of knowledge networks must allow UA and UE units to be interoperable from Army to Joint, Interagency and even Multi-National levels. Although information exchange requirements are not quantifiable at this time, it can be assumed that at a minimum the networks must provide for joint information distribution and exchange.

Importance of Information Engineering in Knowledge Network Development

Information engineering was an important component in the specification, design, implementation, and demonstration of the prototype knowledge network. We believe that successful implementation of an operational network will demand a thorough information engineering process that can account for unanticipated IRs, because of the uncertainty of future mission requirements.

Organization of Information Requirements

The primary outcomes from the information engineering process are the identification and organization of IRs, which are the basis of system requirements. Information requirements are organized by activity phase to specify the information demand sequence and frequency of need. The results of information engineering for the UA organize IRs into three categories, training, operations, and a third more general category covering a variety of other needs. The results of this engineering effort specify required knowledge network capabilities to support UA activities to train, plan, prepare, deploy, rehearse, conduct tactical operations, and support the Soldier.

User Interface

Details of the user interface were not the primary focus of this research. Nevertheless, results of the prototype demonstration indicated the utility of improvements in the user interface design and implementation. For example, the participants in the demonstration indicated that direct links should be provided to specific documents that a user would be likely to search for, such as FMs and TSPs. In addition, links to information from a common source, such as the HSOC, can also facilitate its use. Such links could provide easy access to plans, guidance, and orders. Other suggestions from demonstration participants also addressed user interface issues,

including integrating the searching interface with the battle command system, providing audible or visual alerts for information updates, and download of personal items to portable digital assistants. These and other user interface requirements should be identified as a result of the information engineering process.

Research and Development Needs

The results of the development effort show the potential benefits of technologies for knowledge networks, but also indicate the additional work that will be required to implement them. We briefly list areas where such research is needed.

1. *Enumeration of information needs and sources.* Information engineering should continue to determine requirements for more complete knowledge networks. The analysis should envision the wide range of activities that will be conducted and trained by Future Force units.
2. *Testing concepts for use of features in simulated environments.* Some of the concepts developed in the prototype need to be tested in more realistic environments to discover how they might be used and to determine their utility. For example, although blogs were included in the prototype, we did not develop a detailed concept of operations for this feature. Further research is needed to identify potential methods for using features such as blogs, and to anticipate the potential benefits and pitfalls of these methods. The development work should be followed by empirical evaluations in which they are used in a simulated mission with realistic level of complexity and IRs.
3. *Testing and optimizing organizational constructs.* We have specified fairly simple methods of banding and user profiling to organize information for efficient retrieval. Future research should attempt to optimize these methods, producing, for example, the best set of rules for defining the information bands. Evaluation of improved organizational constructs can combine analytical and empirical methods. For example, it may be possible to analyze the content of IRs to derive analytically the optimal number of bands or the distribution of information across bands. The results of the analytical evaluation would then be confirmed by an empirical evaluation in a realistic mission scenario.
4. *Prototype enhancements.* There are many enhancements possible to the components of the prototype knowledge network. The enhancement process should first address those components in which it is judged that substantial benefits can be obtained through a minimum development effort.
5. *Overall prototype evaluation.* Some of the most interesting questions about the effectiveness of knowledge networks, such as the effect of their use on the decision cycle, must await the development of complete prototype that operates in a realistic information environment. A variety of study designs can provide specific guidance to issues in the development and implementation of knowledge networks.

In the Future Force, information will be more plentiful and its control will be more important to mission accomplishment than it is today. The availability of tools that facilitate the

construction and sharing of knowledge based on the available information will enhance the capabilities of the Future Force. The prototype knowledge network developed for this project illustrates some of the capabilities that could be able to enhance the performance of UAs. The results of this research can be used to guide future research and development efforts to provide operational knowledge networks for the Future Force.

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Appendix A

Acronyms

ABLE	Agent Building and Learning Environment
AKE	Army Knowledge Enterprise
AKM	Army Knowledge Management
AKO	Army Knowledge Online
APOD	Aerial Ports of Debarkation
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ATIA-M	Army Training Information Architecture–Migrated
ATSC	Army Training Support Center
AUTL	Army Universal Task List
BCOTM	Battle Command on the Move
BFA	Battlefield Functional Areas
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CALL	Center for Army Lessons Learned
CBRN	Chemical, Biological, Radiological, or Nuclear
CBT	Computer-based Training
CFX	Command Field Exercise
CGF	Computer Generated Forces
CIAgent	Constructing Intelligent Agents
CIS	Command Information System
CJCS	Chairman of the Joint Chiefs of Staff
CJTL	Combined Joint Task List
CMF	Content Management Framework
CMO	Civil Military Operations
CONUS	Continental United States
COP	Common Operational Picture
CPX	Command Post Exercise
CTC	Combat Training Center
DA	Department of the Army
DIDb	Distributed Information Database
DTML	Dynamic Template Markup Language
FCS	Future Combat Systems
FM	Field Manual
FRAGO	Fragmentary Order
GIG	Global Information Grid
HSOC	Home Station Operations Center

HTML	Hypertext Markup Language
IMAP	Internet Message Access Protocol
INTSUM	Intelligence Summary
IR	Information Requirement
IS	Information Superiority
ISR	Intelligence, Surveillance, and Reconnaissance
JCS	Joint Chiefs of Staff
JTF	Joint Task Force
KN	Knowledge Networks
MCO	Major Combat Operations
METL	Mission Essential Task List
MTP	Mission Training Plan
NBC	Nuclear, Biological and Chemical
NCA	National Command Authority
NCO	Noncommissioned Officer
NRFTT	Networkable, Reconfigurable, Full-Task Trainer
O&O	Operational and Organizational
OPLAN	Operation Plan
OPORD	Operations Order
ORD	Operational Requirement Document
PA	Public Affairs
PDA	Personal Digital Assistant
PDF	Portable Document Format
PIR	Priority Intelligence Requirement
PS	Postscript
PSYOP	Psychological Operations
RDF	Resource Description Framework
RSS	Rich Site Summary
SF	Special Forces
SME	Subject Matter Expert
SPOD	Sea Ports of Debarkation
SSC	Small Scale Contingency
STRAP	System Training Plan
TESS	Tactical Engagement Simulation System
TM	Technical Manual
TP	Training Plan

TRADOC	U.S. Army Training and Doctrine Command
TSP	Training Support Package
TTP	Tactics, Techniques, and Procedures
UA	Unit of Action
UAMBL	Unit of Action Maneuver Battle Lab
UE	Unit of Employment
UJTL	Universal Joint Task List
URL	Uniform Resource Locator
USAARMC	U.S. Army Armor Center
XML	Extensible Markup Language